1996 RESEARCH HIGHLIGHTS

Air Force Office of Scientific Research
Bolling AFB DC 20332-8080

1996 RESEARCH HIGHLIGHTS

Air Force Office of Scientific Research
Bolling AFB DC 20332-8080

Preface

This volume is the fourth annual issue of *Research Highlights* based on our monthly editions of significant achievements and accomplishments. Although this edition contains a small selection of AFOSR's many research successes in 1995, they are representative of our mission:

- to sponsor and sustain basic research
- to transfer and transition research results, and
- to support Air Force goals of control and maximum utilization of air and space.

The highlights provide brief descriptions of AFOSR's research investment accomplishments, examples of technology transfer, and technology insertion. Their purpose is to provide Air Force, DOD, government, and private sector officials interested in science and technology management with brief accounts illustrating how AFOSR supports the Air Force and DOD missions and the national posture in technology.

AFOSR's integrated management approach fosters bilateral and multilateral partnerships between Air Force, university and industry researchers and Air Force, defense and commercial industrial customers. Last year, our nearly 2,000 active research tasks spawned more than 413 significant technology or product applications, more than one-half of these encompassed direct transfers to U.S. industry, with military as well as commercial benefits.

The diverse and wide-ranging scientific efforts in this volume share the common denominator of quality research. Some of the research highlighted here will find its way into currently deployed Air Force systems; some will not reach maturity until we enter the 21st century. These accomplishments demonstrate how, in consonance with its motto, "Building Partnerships with Excellence and Relevance," AFOSR fulfills its important role as a technology transition broker. With this vision, AFOSR continues to provide the Nation with the basic knowledge for new and advanced technologies to meet the challenges of the future.

Preceding Page Blank

Contents

Directorate of Aerospace and Materials Sciences

Researcher Develops Cost-Saving Approach to Processing Carbon Composites

Dr. W.J. Lackey of the Georgia Tech Research Institute has discovered a new approach to fabricating carbon-carbon composites which offers drastic reductions in the materials fabrication costs and improved oxidation resistance. Although carbon-carbon composites offer excellent mechanical properties and have found a wide variety of applications in Air Force systems, they have two drawbacks: high cost due to long fabrication time and poor oxidation stability. However, by using a forced-flow, thermal gradient chemical vapor infiltration (FCVI) process, Lackey reduced the processing time for a full density part one centimeter thick to eight hours. This represents more than an order of magnitude reduction in process time compared to conventional chemical vapor infiltration processes. Lackey's process also makes it possible to distribute layers of silicon carbide (SiC) or other oxidation-stable materials throughout the material, greatly increasing its oxidation resistance.

In the FCVI process, the "preform" which can be made with cloth lay-ups, weaving filament winding or other means, is contained within a special holder. The holder eliminates the need for preform binders and binder "burn-out" steps. Lackey also designed the holder to create a thermal gradient in the part which leads to the uniform deposition of carbon matrix throughout the preform. Lackey used a 50 percent concentration of propylene (C_3H_6) in a hydrogen carrier gas to "densify" parts as thick as two centimeters in a greatly reduced amount of time. His process produces a dense, uniform matrix yet it is very simple to change the composition of the matrix by changing the gas "flown" throughout the system. This makes it possible to distribute layers of silicon carbide (SiC) or other oxidation-stable materials inside the matrix. The FCVI process has been developed over the last ten years for use with silicon carbide composites, but Lackey's research is the first demonstration of the FCVI process for carbon-carbon materials.

Major Air Force applications of carbon-carbon composites includes rocket engine cones and aircraft brakes. The reduced cost and improved oxidation resistance offered by Lackey's work will allow the Air Force to cut costs in fabricating the material while opening up new applications for the composites. Lackey's discovery is also of major significance to private industry where carbon-carbon materials are widely used in such applications as commercial aircraft brakes.

Dr. Alexander Pechenik
Directorate of Aerospace and Materials Sciences
(202) 767-4962, DSN 297-4962

CVI GAS INJECTOR

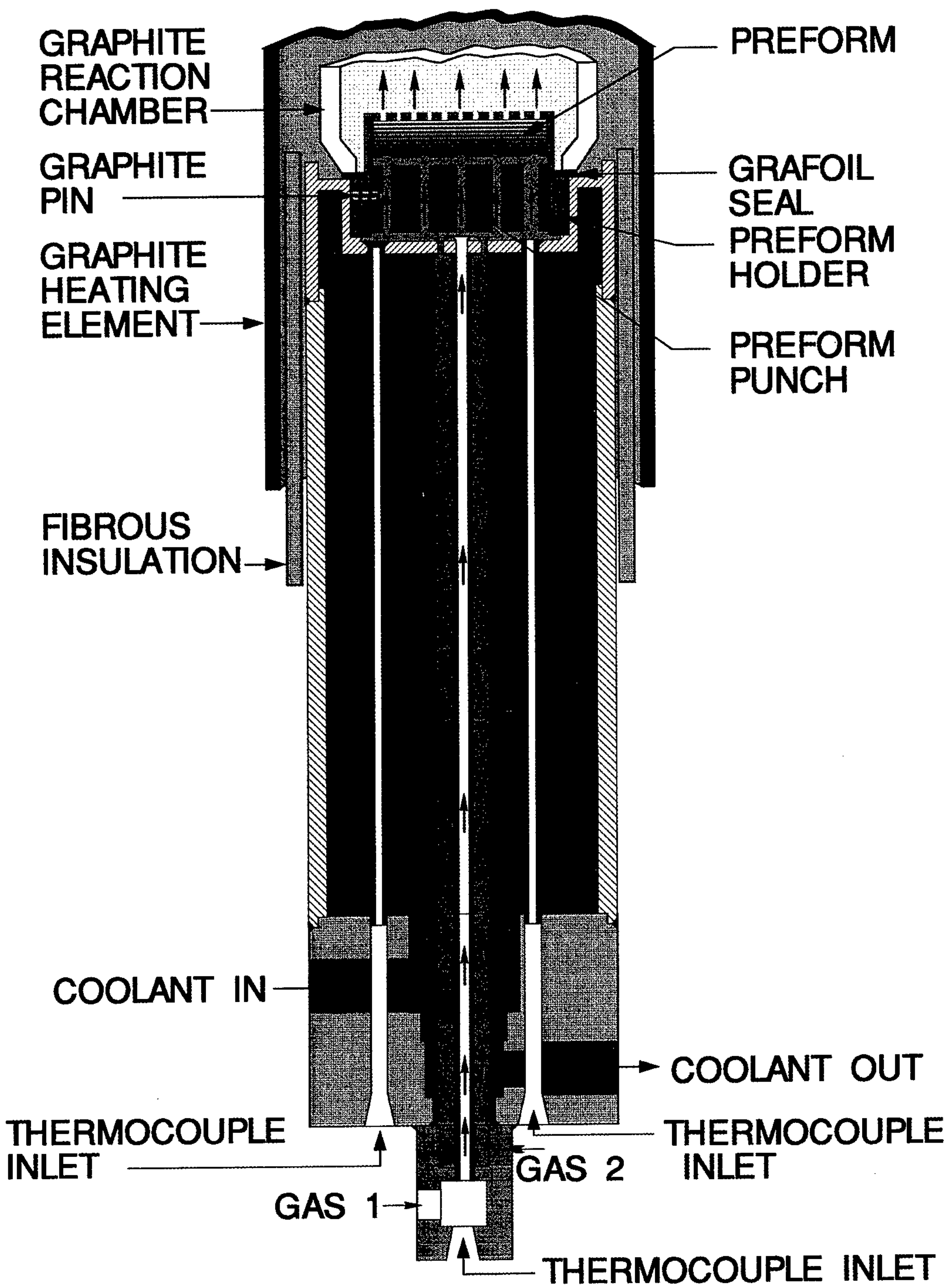


Figure 1. Georgia Tech Research Institute investigators have discovered a new approach to fabricating carbon-carbon composites that is significantly less costly than current approaches. It also offers improved oxidation resistance. Carbon-carbon composites are used in a wide variety of Air Force systems, including rocket engine cones and aircraft brakes. Figure 1 illustrates the forced-flow, thermal gradient chemical vapor infiltration (FCVI) process used to manufacture the composite.

Scientists Derive Theory for Adsorption of Co-contaminant Species in Soils

Armstrong Laboratory researchers have developed a theory which addresses a major problem in predicting the ultimate behavior of contaminants at Air Force sites where more than one contaminant is present. Dr. Joseph Feldkamp and Dr. Tom Stauffer, AFOSR-supported researchers at Tyndall AFB Fla., have derived a theory which describes the partitioning of binary solvents when placed in contact with charged expandable organo-clays such as montmorillinite. This is significant because the DOD and industry are increasingly required to clean up environmental sites in which several contaminants are present in mixtures.

The developed theory predicts the contaminant phase compositions adsorbed on the clay particle surfaces given their pure phase concentrations. It highlights the central role the relative solvent dielectric constants play in the observed behavior. Feldkamp and Stauffer used Fourier Transform Infrared Spectroscopy (FT-IR) to directly measure phase compositions of selected binary solvents adsorbed on montmorillinite clay surfaces. They found excellent agreement between theory predictions and experiment when the dielectric constants of the two solvents of a binary solvent combination are relatively far apart. This is important since prior to their finding, all sorption and consequent retardation of the movement of nonionic chemicals in ground water had been attributed solely to physical adsorption onto soil organic matter. This new insight provides a better understanding of the environmental transport of organic chemicals and has significantly increased knowledge of the interaction of nonionic organic chemicals with naturally occurring geologic materials.

A further consequence of their research pertains to the alteration of the mechanical properties of a clay-like soil when subjected to changing solvent phase compositions. Feldkamp and Stauffer's work showed that not only do surfaces exert an influence on interfacial solvent compositions, but the partitioning itself exerts a direct and profound influence on the mechanical properties of clay soils. It is critical to understand these mechanical effects since clays are commonly used as barriers to contaminant movement in landfills and around contaminated sites.

Capt Brian Sanders
Directorate of Aerospace and Materials Sciences
(202) 767-6963, DSN 297-6963

New Flow Control Techniques for C-17 Based on AFOSR Research

McDonnell Douglas Aerospace (MDA) is conducting a technology development program on active flow control concepts for future improvements to the C-17's propulsion system. New technologies include active mixing enhancement for plume IR and jet noise reduction and pulsed fluidic thrust vectoring for enhanced maneuverability. These improvements would enhance the C-17's affordability, survivability, and environmental compliance beyond current specifications and regulations.

These innovative technologies are based on work by a team of AFOSR-sponsored researchers at Georgia Tech led by Professor Ari Glezer, working in collaboration with Drs. Valdis Kibens and David Parekh and Mr. David Smith of McDonnell Douglas. The team learned how to actively control fundamental fluid dynamic instabilities in jet flows and to vector hot jet gases. These innovative active jet control techniques employ a set of piezoelectrically driven, pulsed fluidic, or synthetic jet actuators placed at the jet lip. These actuators dramatically alter the jet's development by exciting fundamental instabilities that are amplified by the flow. Asymmetric excitation of the jet leads to more intense turbulent mixing on one side of the jet than on the other, which tilts or

Passive and Active Control of Hot Plume Protects C-17 Loadmaster

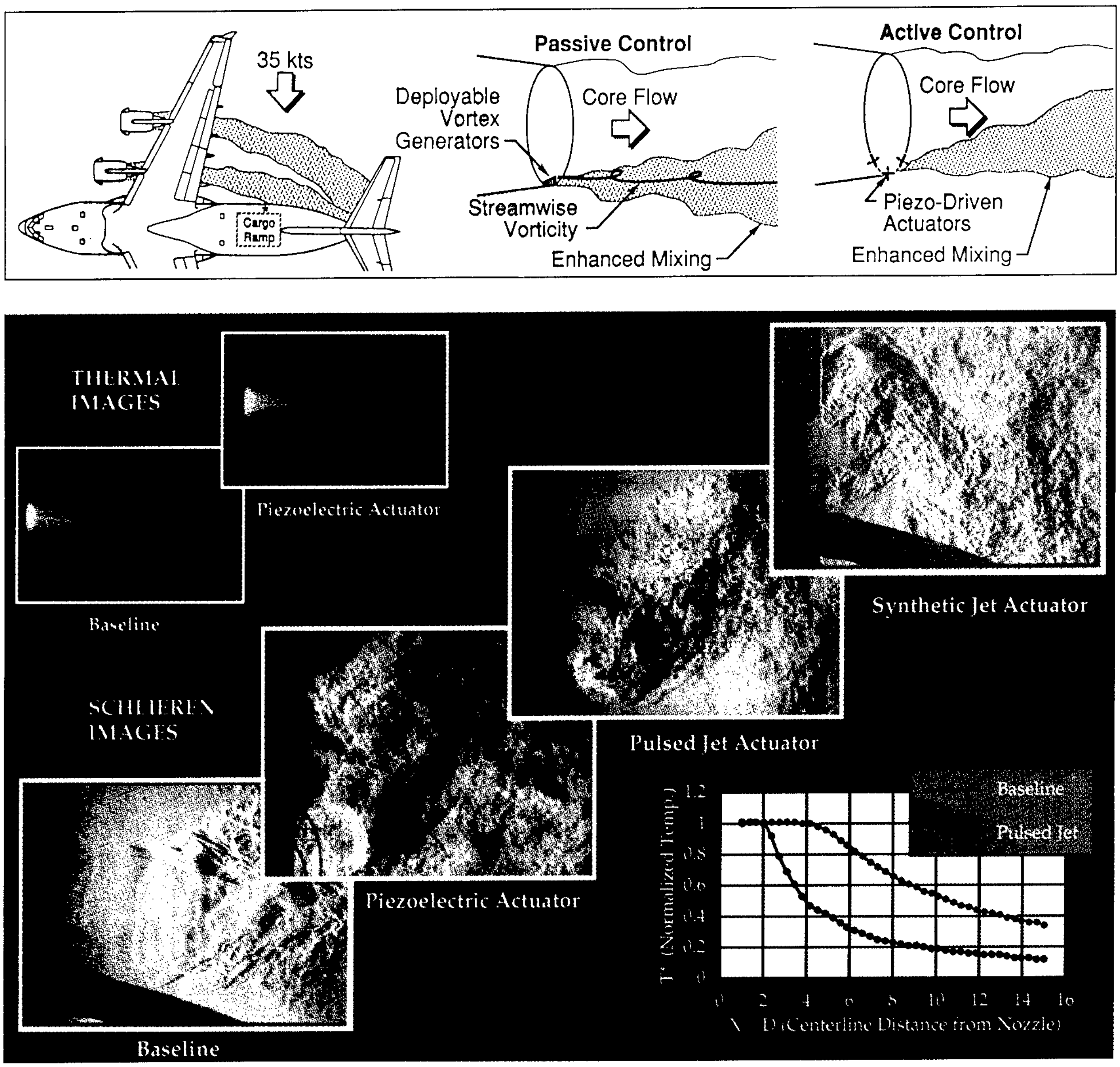


Figure 2. Several active flow control actuators are now being explored by McDonnell Douglas to reduce the temperature of hot jet exhaust gases. The thermal images figure illustrates the jet response to each actuator type, and shows the reduction in temperature achieved with piezoelectric actuators.

vectors the jet off axis. These active control techniques illustrated in the figure have been transitioned to the McDonnell Douglas C-17 Improvements & Derivatives Group which is performing the conceptual design and system integration studies. Professor Glezer's pioneering work is based solely on AFOSR support for the past eight years.

Dr. James McMichael
Directorate of Aerospace and Materials Sciences
(202) 767-4936, DSN 297-4936

Affordable Fabrication of Advanced Ceramics Through Low-Temperature Oxidation

Prof. Ken Sandhage of Ohio State University has conceived and successfully demonstrated a novel approach to fabricating ceramics. The approach, called Solid Metal-Bearing Process (SMP), allows fabrication of ceramic materials by oxidizing dense parts formed by pressing a mixture of metallic and ceramic powders. SMP looks particularly promising for manufacturing ceramic-matrix composites (CMCs), ceramic bearings, and high-temperature ceramic parts used in Air Force and commercial applications.

Technically, SMP is similar to the traditional methods of powder metallurgy: metal and sometimes ceramic powders are blended, shaped into a desired form, and then sintered at high temperatures to produce dense metallic or dense metallic-ceramic parts. However, SMP substitutes the final step of high temperature sintering required by powder metallurgy procedures with a new step of well-controlled, low-temperature oxidation of the dense part. Using the SMP technique over traditional approaches offers a significant advantage: using the chemical reaction of oxidation rather than simple heating produces dense refractory ceramics at much lower temperatures than needed by traditional techniques. The reduction in processing temperatures should lead to huge savings in industrial processing of highly refractory ceramics and composites.

SMP offers another big advantage over the conventional processes of ceramics manufacturing: if fine-tuned, the process allows near-net shaping of ceramic parts. During oxidation, the specific volume of alkaline metals decreases, while the specific volume of other metals in the mixture increases. By carefully designing the composition of the starting powders, Professor Sandhage has successfully demonstrated the ability to achieve less than a one percent change in dimensions of the parts before and after sintering. In manufacturing environments this would greatly reduce the need to grind and polish the ceramic parts, a step normally required after sintering to achieve proper dimensions.

Dr. Alexander Pechenik
Directorate of Aerospace and Materials Sciences
202-767-4962, DSN 297-4962

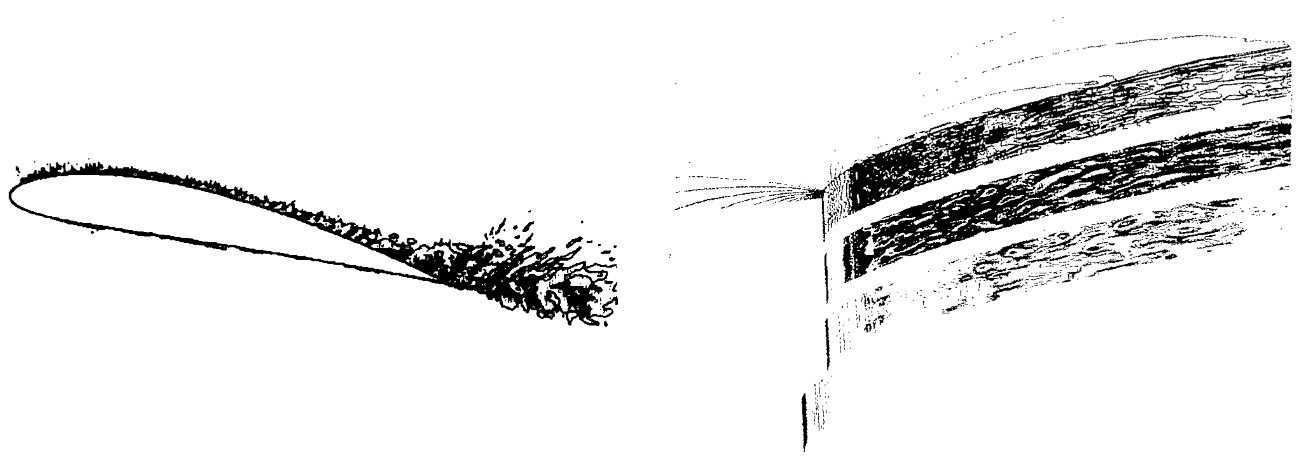
Advance in Air Flow Simulation May Cut Aircraft Fuel Costs, Increase Range

Dr. Parviz Moin of Stanford University has completed the first compressible Large Eddy Simulation (LES) of the flow over an airfoil. This is a breakthrough step in AFOSR's ongoing sponsorship of research to develop LES techniques to predict the turbulence structures which exist in turbulent flows over actual flight-vehicle geometries. Aircraft designs based on LES techniques would reduce viscous drag thereby increasing flight range and cutting fuel costs by hundreds of millions of dollars over 10 years.

Dr. Moin's achievement represents a major advance because LES techniques, unlike current turbulence model-based methods, are capable of predicting the full spatial and temporal evolution of turbulence structures which cause viscous drag in turbulent flows.

Detailed knowledge of these structures, their characteristics, and their flow evolution over complex flight vehicle geometries could revolutionize the design of military and commercial airplanes. Aircraft designers could then use the information to develop both transport and passenger aircraft designs which minimize drag.

Dr. Leonidas Sakell
Directorate of Aerospace and Material Sciences
202-767-4935, DSN 297-4935



3A **3B**

Figure 3. A basic research effort at Stanford University is advancing Large Eddy Simulation (LES) techniques to predict turbulence which affects aircraft drag. The figure illustrates the LES solution with two views of the growth of compressible turbulence structures in the flow over a NACA 4412 airfoil at a flight Mach number of 0.2, twelve-degree angle of attack and chord Reynolds number of 1.64 million. Figure 3A illustrates the streamwise development of the turbulence, indicating a large region of boundary layer separation at the rear quarter of the airfoil. Figure 3B shows planform views of the turbulence structures at different vertical positions within the boundary layer. The top position is at the surface and the bottom position is just outside the edge of the boundary layer.

Improved Processing Promises More Affordable Intermetallic Alloys

Materials scientists at the Air Force's Wright Laboratory have developed a quantitative criterion for predicting fractures in materials during high-temperature processing. Drs. Lee Semiatin and Verkat Seetharaman say this standard can be used to design component manufacturing processes. In multistep processes, the criterion can quantify changes in processing constraints caused by changes in the material's microstructure from one step to the next.

This development will make titanium aluminide (TiAl) and other intermetallic alloys more affordable for the Air Force. The higher-temperature, load-bearing substitutes for nickel-based superalloys can be used in applications from jet engines to hypersonic airframe components.

Past research on the wrought processing of TiAl concentrated on the evolution and control of microstructure. By contrast, processing conditions to avoid fracture were chosen largely by trial and error. The new model lets researchers define processing windows for microstructure development and workability, and allows them to choose the best microstructure for each application.

For example, gamma titanium aluminide (TiAl) alloys serve as a good model material. TiAl base materials are prime candidates to replace nickel-based superalloys in jet engines because they have excellent strength-to-weight ratios and they resist oxidation and creep. Working with the directorate's Processing Science Group, Drs. Semiatin and Seetharaman studied TiAl alloy failures and found that conventional processing — rolling, forging, extrusion — cause intergranular cracking. At high temperatures, grain boundary sliding becomes an important deformation mechanism, especially in highly alloyed materials like intermetallic alloys.

During their research, the group learned that microcrack initiation controls TiAl failure and adopted a brittle-fracture criterion. Intergranular failure starts at a critical value of the product of the applied effective stress and the square root of the grain size over a large temperature regime. Once these intergranular cracks begin, sustaining low-tensile-stress levels can lead to gross failure.

Capt. Charles H. Ward
Directorate of Aerospace and Materials Sciences
202-767-4960, DSN 297-4960

New Engineering Tools Bolster Aging Air Force Aircraft Fleet

Under an AFOSR research grant, Purdue University researchers have developed engineering tools that will help evaluate and improve the structural integrity of the Air Force's aging fleet of aircraft. Results of this research directly support the efforts of Air Force labs and Air Logistics Centers to keep weapons systems operational long beyond their original design lives.

Prof. Tom Farris is studying aircraft materials fatigue due to fretting, which occurs as airframe parts wear during service. He developed a novel experimental method that simulates operational fretting fatigue, and an accurate finite-element model that can calculate stress, strain and displacement fields induced by fretting. Results of this research will help engineers characterize aircraft materials wear during operational service.

Prof. Ben Hillberry is developing a probabilistic approach to predicting fatigue life due to defect formation in structural materials. These are caused mainly by material inclusions that lead to corrosion pits and that may initiate cracks during aircraft operation.

Prof. Skip Grandt is characterizing the degradation of material properties due to aging, and analyzed the effect of initial damage and material variability on residual strength and life in the presence of multiple-site cracking. This cracking leads to catastrophic failure in aircraft structures because several damage sites link up. His initial work showed that material strength degrades very little with age, while stiffness degrades 5 to 10 percent over long service periods. This answers crucial questions about materials' ability to retain original strength and stiffness over long service periods.

Prof. C.T. Sun is studying the effect of composite repairs on metal airframe structures, a technique the Air Force has used in C-141 fleet repairs. He showed that thermal residual stresses induced by composite patching have an adverse effect on crack arrest for small loadings, and that more work is needed to characterize the stress-free temperature of the adhesively bonded structure. Before this work, which will add to the safe operation of repaired aircraft structures, there was no way to analyze composite patches.

Research efforts will continue through summer 1997, guided by a government-industry advisory panel of representatives from AFOSR, Wright Lab, the AFMC/Aeronautical Systems Center, Oklahoma City Air Logistics Center, Alcoa, McDonnell-Douglas, the FAA and NASA. The grant, funded through an AFOSR FY93 Multidisciplinary University Research Initiative, involves six faculty and more than 15 graduate students in the Schools of Aeronautics and Astronautics, mechanical Engineering, Materials Science and Engineering, and Statistics.

Dr. Walter F. Jones
Directorate of Aerospace and Materials Sciences
202-767-0470, DSN 297-0470

Directorate of Physics and Electronics

Research Team Measures Key Alloy Used in Optoelectronics

A University of Michigan research team led by professor Palab Bhattacharya has successfully made the first measurements of several key properties of silicon germanium (SiGe). The semiconductor alloys of SiGe have great potential for electronic and optoelectronic applications in Air Force signal processing technology, but they must be accurately measured in order to model devices. The availability of this type of data can have a substantial impact on Air Force signal processing technology.

The material properties of the SiGe semiconductor alloys are compatible with prevailing silicon technology while offering substantial performance advantages. The ability to accurately measure the key properties of SiGe is critically important for the effective modeling of electronic and optoelectronic devices. Without accurate data the models would likely be faulty, leading to several expensive and time-consuming iterations in perfecting new device structures. The Michigan experiments were buttressed by a collateral theoretical effort that guided the experiments and helped to interpret the results. This integrated research effort has been supported by AFOSR since its inception in 1991.

The materials parameters measured and published for the first time included the determination of the impact ionization coefficient, the threshold energy for electrons and holes, the alloy scattering potential and the Hall factor. The results of this research are particularly timely since IBM and Analog Devices recently signed an agreement to develop the first commercial products incorporating SiGe alloys. In anticipation of the substantial impact on Air Force signal processing technology, Wright Laboratory researchers are closely monitoring these efforts.

Dr. Gerald L. Witt
Directorate of Physics and Electronics
(202) 767-4932, DSN 297-4932

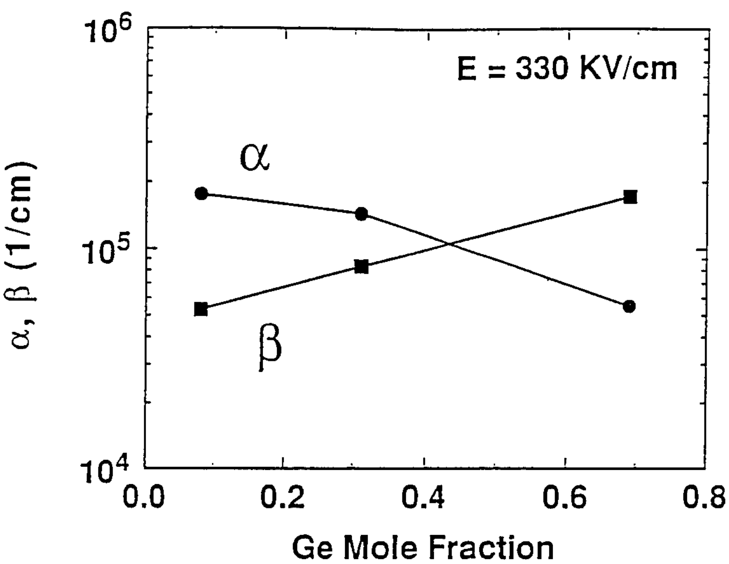


Figure 4. Air Force signal processing technology may soon benefit from basic research results which show substantial performance advantages offered from silicon germanium, a semiconductor alloy. The graphic depicts the first measured values of impact ionization coefficients for electrons (alpha-α) and holes (beta-β) as a function of the alloy composition. This data is important for accurate device modeling.

Study of Biological Systems Reveals Applications to Magnetic Materials

Scientists at the University of California, Santa Barbara studying "mesoscopic" magnetism have observed phenomena which help to answer questions about the density limits of reliable information storage and suggest the possibility of new quantum-based magnetic devices. This research holds great promise for a number of Air Force applications including the use of "smart" biomagnetic coatings for the magnetic imaging of structural defects in aging aircraft, high thermal conductivity ferrofluid seals, and new refrigerants for magnetic cooling refrigeration systems.

In their research, Professor David Awschalom and his colleagues took advantage of the small-length scale of magnetic biological systems, using the protein ferritin among the smallest known magnetic particles whose eight-nanometer shell contains up to 4,500 ferric ions. Awschalom's group was able to synthesize the new magnetic materials directly within empty protein shells. They demonstrated that a controlled number of ferric ions, as few as 100, could be biochemically introduced into these shells. These artificially-engineered proteins can replicate the naturally-occurring mineral ferrihydrite. They can also be made to form other "designer" materials with the introduction of magnetite, iron sulfide, manganese oxide and uranium oxide. The researchers found that the magnetic moment of these new artificial ferrimagnetic particles is an order of magnitude larger than that of the naturally occurring ferrihydrite, making them much more sensitive to applied magnetic fields. This also makes them more valuable in studying the volatility of memory as the size of the particles is reduced. Because of their large surface to volume ratio, the surface "spins" can be used to tune magnetic properties microscopically.

Dr. Harold Weinstock
Directorate of Physics and Electronics
(202) 767-4933, DSN 297-4933

New Optoelectronic Materials Developed from Non-Stoichiometric GaAs

Teams of university and Air Force physicists have developed promising optoelectronic materials using quantum wells formed from thin layers of dissimilar-compounds semiconductors like gallium arsenide (GaAs) and aluminum gallium arsenide (AlGaAs). Detectors and circuits made with these optoelectronic materials are faster, tolerate radiation better and use less power than electronic materials. Thus, they are aimed at replacing electronics in advanced Air Force avionics systems.

These new materials combine two features that are usually mutually exclusive: very narrowly defined spectral windows (sharp excitons) and an ability to detect very short pulses (ultrafast lifetimes). Fast saturable absorbers, electro-optic sampling and photorefractive storage, all critical building blocks for an effective photonic signal-processing system, require these features.

Purdue University physicists produced multiple quantum wells of GaAs/AlGaAs with both these attributes by using a low-temperature growth technique and molecular beam epitaxy. This produced As-rich material that, when annealed, exhibits very fast lifetimes and, when used in quantum wells, exhibits sharp excitons for the first time. Such quantum wells strongly resist electron leakage, a third important feature that is required in low-noise detectors for Air Force avionics.

University research teams at Purdue, Cornell and the University of California at Santa Barbara, and at the Air Force's Rome and Wright Laboratories have developed these materials with AFOSR support over the last three years.

Dr. Gerald Witt
Directorate of Physics and Electronics
(202) 767-4932, DSN 297-4932

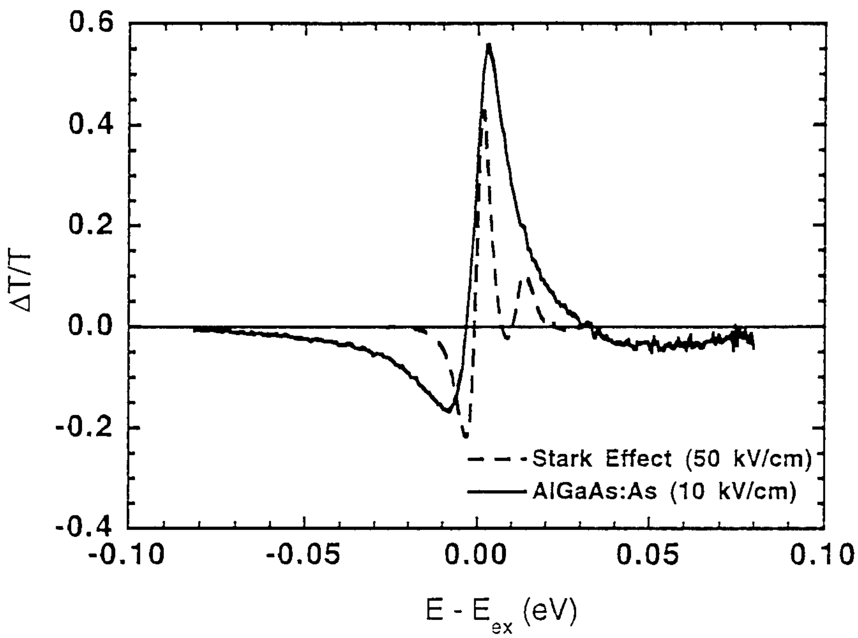


Figure 5. The development of new optoelectronic materials offers better performance for Air Force avionic systems. The graph shows a comparison of optoelectronic responsivity (ΔT/T) of normal GaAs (Stark Effect) and non-stoichiometric GaAs (AlGa As : As). While slightly broader in energy spread, the non-stoichiometric GaAs sample has a usefully sharp excitonic feature. Its responsivity is somewhat greater.

Optimized Detectors Improve Infrared Imaging Systems

Researchers at Wright Laboratory and the University of Dayton developed and validated a new model for p-type quantum well long-wavelength infrared detectors. This work could ultimately be used to double the efficiency of infrared imaging systems used in Air Force night tactical operations, bad weather and space-based surveillance.

The new detectors could someday replace the industry standard n-type GaAs/AlGaAs quantum well infrared detectors, which require several array-processing steps. Unique properties of the GaAs valence band eliminate this limitation in p-type GaAs/AlGaAs quantum wells. The work of materials scientist Dr. Gail J. Brown at Wright Lab and solid-state theorist Dr. Fran Szmulowicz at U.D. made it possible to create transverse detector arrays from layered III-V semiconductor materials that improve infrared imaging systems used in night tactical operations, bad weather and space-based strategic surveillance. Their results show that optimum configurations for p-detectors more than double infrared light absorption.

Drs. Brown and Szmulowicz made photoresponse measurements of three p-type GaAs/AlGaAs multiple quantum well materials. Each had a slightly different well width that increased by 5Å increments from 30Å to 40Å. At the same time they developed a model of infrared absorption in p-type quantum wells, and performed model-based calculations to predict absorption magnitude as a function of well width.

Theoretical results show that optimum absorption should occur at a GaAs quantum well width for which the final state in the absorption process occurs at the AlGaAs layer barrier energy. At the system level, this effect would optimize the detector's sensitivity. AFOSR has been the sole funder of this work for three years.

Maj. Michael Prairie
Directorate of Physics and Electronics
202-767-4931, DSN 297-4931

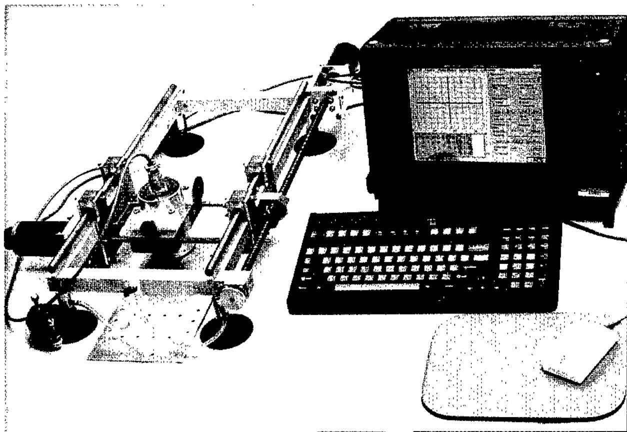
New Nondestructive Evaluation Tool Identifies Corrosion in Aging Aircraft

Researchers at Iowa State University have built a portable tool that could help detect corrosion in aging aircraft. With AFOSR funding, physicist James Rose and colleagues built the instrument using a lunch-box-sized personal computer to find wall loss between the first and second layers in lap joints. This will help the Air Force maintain 20- and 30-year-old aircraft, particularly if the Oklahoma City Air Logistics Center at Tinker AFB adopts it to inspect the fleet of C/KC-135 aircraft it services.

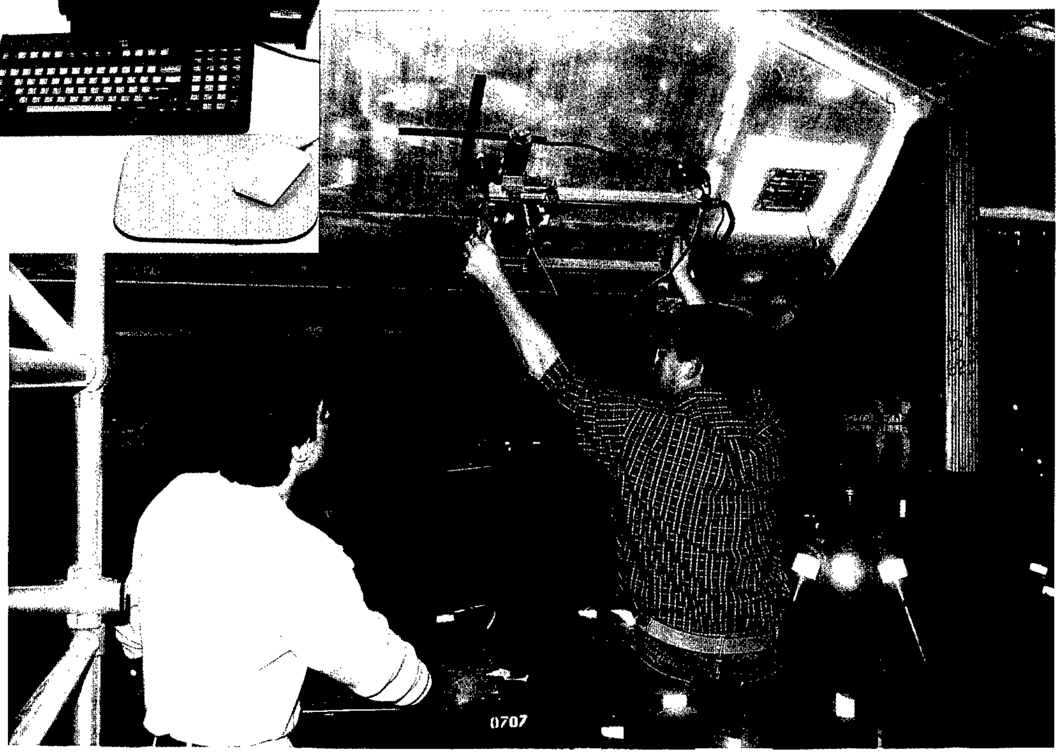
The instrument, built at Iowa's Center for Nondestructive Evaluation to find wall loss in lap splices, records the transient eddy-current response of an air-core coil next to the lap splice. Signals are digitized with 16-bit resolution at a sampling rate of 1 megasample and 1,000 repetitions per second. It was tested on simulated samples whose wall losses were machined, and on actual corroded lap splices supplied by Tinker AFB and Boeing. The instrument's measured response agreed with theoretical calculations based on a model developed under the same program.

The instrument was evaluated in August 1995 at Tinker AFB during an Air Force-sponsored blind trial of new technology for detecting corrosion in aircraft panels. It performed well during two days of inspection, readily detecting corrosion in the second layer. It is now one of two instruments being cited publicly as reliable and as a candidate for further study.

Dr. Harold Weinstock
Directorate of Physics and Electronics
202-767-4933, DSN 297-4933



6A



6B

6C

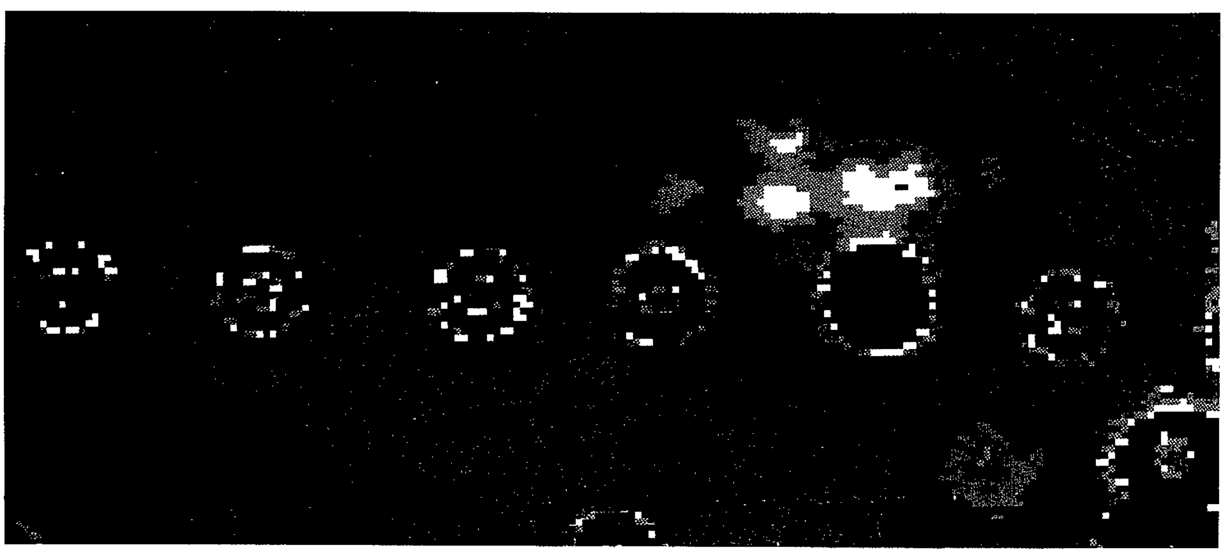


Figure 6. Iowa State University researchers have built a portable pulsed eddy-current instrument capable of detecting wall loss between the first and second layers in aircraft lap joints. Figure 6A features the instrument which displays a line scan of a typical corrosion-induced transient voltage response as a function of time. Figure 6B depicts the scanner in use on a KC-135 tanker at McClellan AFB. Figure 6C shows a detailed scan of hidden corrosion in a sample of aircraft skin provided by Boeing Corporation. The red circles indicate rivets, while the large dark blue through yellow region indicates the presence of substantial corrosion.

New Architecture Offers a Modular Approach to Plasma Modeling

A transcontinental team of AFOSR-sponsored corporate and academic researchers has released software with a new approach to plasma modeling. The heart of their Object-Oriented Particle-in-Cell (OOPIC) system is its use of library architecture. This flexible environment lets researchers use OOPIC software modules like building blocks, to tailor specific approaches to a variety of plasma problems. This powerful modeling paradigm will help Air Force researchers investigate the physics of electron-beam-driven sources of ultrahigh-power microwave radiation for communications, surveillance and directed-energy weapons.

Electrical engineering Prof. Ned Birdsall (University of California-Berkeley) led the team, which included computer scientist Prof. James Acquah (George Mason University) physicist Dr. Tom Gladd (Berkeley Research Associates), and electrical engineer Dr. Mark Rader, who managed an OOPIC software repository at historically black Knoxville College. The researchers used off-the-shelf commercial products to create the user-friendly OOPIC framework, and developed the complex physical models needed for accurate simulations.

This is a fundamental break from the massive, bug-prone FORTRAN plasma-simulation codes whose logic is harder to follow, whose software is harder to break into modules, and whose modules are less flexible. Twenty-four of the nation's top plasma researchers received copies of the software and a tutorial at an OOPIC Release Workshop. Phillips Laboratory researchers noted the OOPIC 's architecture works particularly well with parallel-processing hardware.

AFOSR has been sole funder of the project, launched three years ago as part of a plasma-modeling initiative. Its goal was to upgrade the approach to problems involving the interaction of relativistic charged particles and electromagnetic fields.

Dr. Robert J. Barker
Directorate of Physics and Electronics
202-767-5011, DSN 297-5011

New Digital Memory System Stores Huge Image Data Files

Collaborative investigations by applied physicists at the universities of Oregon and Washington have demonstrated a spectroscopic optical memory technology that can store more than 100,000 binary images with selectable input/output (I/O) rate anywhere between the T.V. frame rate of 30 frames per second (fps) and 10,000 times faster. Because data addresses are not spatially encoded, the medium can be stationary, reducing access latency to a desired data block by a factor of 1,000.

Essential elements of Air Force battlefield preparedness include the ability to capture, store, transmit and process images. A central component in these elements is a digital memory system like the one developed by AFOSR-sponsored researchers Thomas W. Mossberg at Oregon and W. Randall Babbitt at Washington involving a technology called persistent spectral hole burning.

Mossberg and Babbitt recently demonstrated optically accessed memory whose extrapolated density is more than 500 gigabytes per square inch and whose frame rate can be chosen across a wide range, from 30 fps to 100 million fps. The stationary medium reduces latency associated with rotating disks–100 microseconds average file access time–by three orders of magnitude.

Combining the chirped-carrier technique with extended field of view imaging optics, they can store and retrieve image sequences at up to 100 million fps, within the limits of optical beam power. HDTV image formats could easily be stored in a 1-square-centimeter memory area. Available 2-dimensional spatial light modulator and charge-coupled device camera technologies limit I/O frame rates. Supercomputer image transfers in sustained parallel formats, or multiplexed telephony switching circumvent these interface devices and can exploit the immense frame rate. This memory technology provides a flexible-image format capability within the bounds of these extremes.

Dr. Alan E. Craig
Directorate of Physics and Electronics
202-767-4934, DSN 297-4934

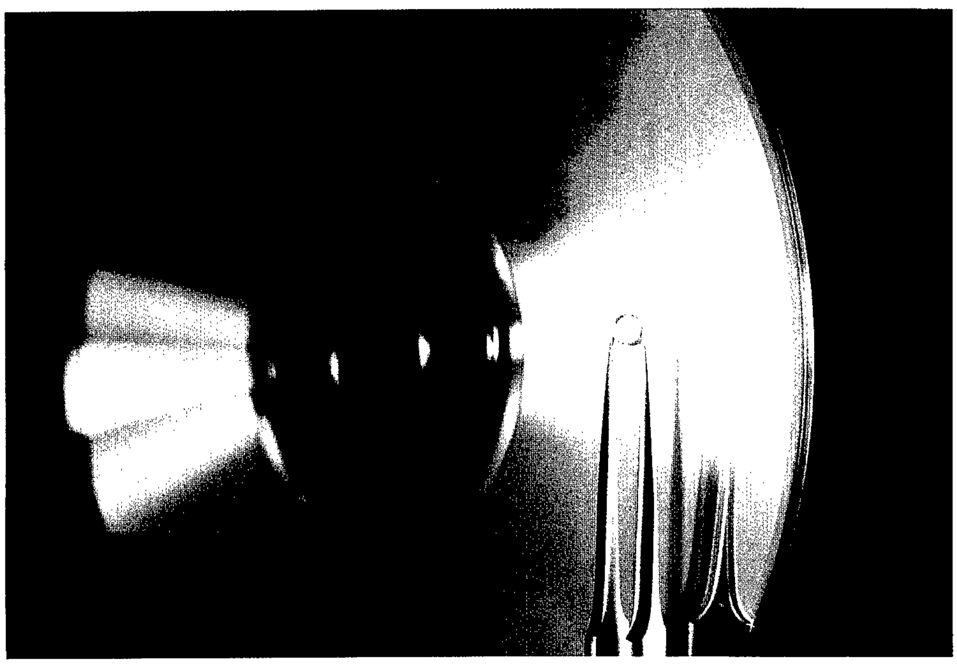


Figure 7. A new digital memory system will contribute to Air Force battlefield preparedness by improving the ability of forces to capture, store, transmit, and process images. Figure 7 shows the YAG crystal used in the storage system. These crystals store data at a record-breaking areal density of 8 gigabytes per square inch. In the background is a standard CD ROM with its much lower areal storage density of about 0.5 gigabytes per square inch.

MRI with Laser-Polarized Noble Gases Produces Superior Images

Professor Will Happer of Princeton University and colleagues at State University of New York at Stonybrook and Duke University have developed a new implementation of magnetic resonance imaging (MRI) using laser-polarized noble gases. This technique uses lasers to enhance the MR signal from noble gases such as helium and xenon, making them easily observable in a conventional MRI scanner. Initial experiments have already yielded spectacular magnetic resonance images of the lungs of laboratory animals, and recently the first images of a human subject have been produced. This technology should provide functional information that can be important in evaluating and treating pulmonary embolisms, emphysema, asthma, lung cancer and a wide variety of respiratory problems. Lung function is an important concern for the DoD in many areas, including lung function of aviators at high altitudes, deep sea divers, and chemical warfare environments.

In addition to medical uses in both military and civilian hospitals and clinics, noble gas MRI has potential applications in non-destructive evaluation and maintenance diagnostics. Because the technology is especially effective in imaging spaces or voids, it may have application for diagnostics on composite materials such as ceramic jet turbine blades. Ceramics are porous enough to allow the infusion of polarized noble gases, particularly into cracks and voids, permitting MRI testing of the structural integrity of the material.

Magnetic resonance imaging with laser-polarized noble gases has been made possible by years of basic physics research in the areas of optical pumping and spin exchange. Optical pumping uses circularly polarized light, most often from a laser, to create a large electron spin polarization in a

Figure 8. Researchers at Princeton University, the State University of New York at Stoneybrook, and Duke University have developed a new magnetic resonance imaging (MRI) device using the laser-polarized noble gases helium and xenon. The use of these gases allows scanning of human organs, such as the lungs and brain, that is not possible with conventional MRI technology. Figure 8 shows the first images of human lungs taken with an MRI using noble gases. The various colors show differing densities of xenon.

vapor of rubidium or similar atoms. In a collision with a noble gas atom, the electron spin of the rubidium atom can be transferred to the nuclear spin of a noble-gas atom. Extremely large nuclear polarizations can be obtained.

Thus far, noble gas MRI experiments have made use of commercial MRI scanners. However, because the signal to noise ratio of the MR signal from laser-polarized noble gases is independent of magnetic field strength, imaging with much smaller fields will be possible. A dedicated MRI unit for noble gas imaging would be small, inexpensive, and easily portable.

Dr. Ralph E. Kelley
Directorate of Physics and Electronics
(202) 767-4908, DSN 297-4908

Directorate of Academic and International Affairs

Japanese Laboratory Hosts AFIT Professor for Opto-Electronic Research

A Japanese industrial laboratory is hosting an Air Force Institute of Technology (AFIT) instructor for a six-month research project under AFOSR's Window on Asia Program. In April, the Nippon Electric Corporation's Opto-Electronics Research Laboratory in Tsukuba, Japan, welcomed Capt. James A. Lott, an AFIT assistant professor of electrical engineering.

Captain Lott's research focuses on design, modeling, characterization, and fabrication of compound semiconductor optoelectronic materials and devices. His research will focus on the characterization of catastrophic optical damage (COD) in red AlGaInP/AlGaAs laser diodes. These lasers emit light in the visible (~600-690 nm) spectrum. Catastrophic optical damage is a primary failure mechanism of these types of lasers, and limits the maximum obtainable output power density. Cleft semiconductor facets act as mirrors and form the laser's resonant cavity. The mirror facets are known to degrade with time for high-power operation. This reduces the laser's efficiency (i.e. raises operational current for a given output power level) and lifetime. The relationship between COD and facet temperature will be investigated using photoluminescence techniques in order to quantify the COD mechanism. Advanced fabrication techniques including the use of dielectric and epitaxial facets coatings will be undertaken with an aim toward demonstrating a "COD-free" red laser.

The Asian Office of Aerospace Research and Development assisted AFIT in developing this opportunity. AOARD is one of AFOSR's two foreign offices. (The European Office of Aerospace Research and Development is located in London.) These offices manage programs to provide access to research and research organizations worldwide for the Air Force Materiel Command's entire technology community.

Gerri L. Zarbo
Directorate of Academic and International Affairs
(202) 767-5013, DSN 297-5013

Canadian Research Exchange Aids Aircrew Training Program

During a two-year research exchange with a Canadian defense unit, Dr. Byron Pierce, an Armstrong Laboratory senior research psychologist, collaborated on research efforts that support Air Force aircrew training during simulated flight of fixed-wing and rotary aircraft. Dr. Pierce recently completed an Engineer and Scientist Exchange Program (ESEP) tour at the Defense and Civil Institute of Environmental Medicine (DCIEM), North York, Ontario.

He collaborated with Canadian scientists on behavioral research that examined the design and use of stereoscopic displays. He worked with sponsor Dr. Lochlan Magee on the development of a tiered simulation testbed for a Sea King helicopter deck landing task. The testbed consists of three-simulators: a low-cost virtual reality simulator to be developed at DCIEM, and two high-end simulators with Fiber Optic Helmet-Mounted Displays (FOHMDs) at the Flight Research Laboratory, Ottawa, Ontario, and the University of Toronto Institute for Aerospace Studies, North York, Ontario.

Dr. Pierce also conducted research on visual perception issues. He studied the effect that shear and magnification disparities have on how people perceive surface inclination and slant in static stereoscopic displays. His experiments also examined interactions between disparity images and superimposed or adjacent zero-disparity displays - like viewing real imagery with superimposed FOHMD images that have disparities.

This work will help the Air Force develop the most realistic, effective flight simulators for rotary and fixed-wing aircraft. Dr. Pierce will collaborate with Dr. Magee and co-investigator Prof. Ian Howard (Institute for Space and Terrestrial Science, York University) on related research in the future.

The exchange program, managed by the Air Force Office of Scientific Research, promotes international cooperation in research and development by exchanging defense engineers and scientists. ESEP offers U.S. military and civilian engineers and scientists onsite working assignments in allied and friendly governments' defense establishments, and reciprocal assignment of foreign engineers and scientists in U.S. defense establishments. This cooperative arrangement avoids duplication of research efforts.

Gerri Zarbo
Directorate of Academic and International Affairs
202-767-5013, DSN 297-5013

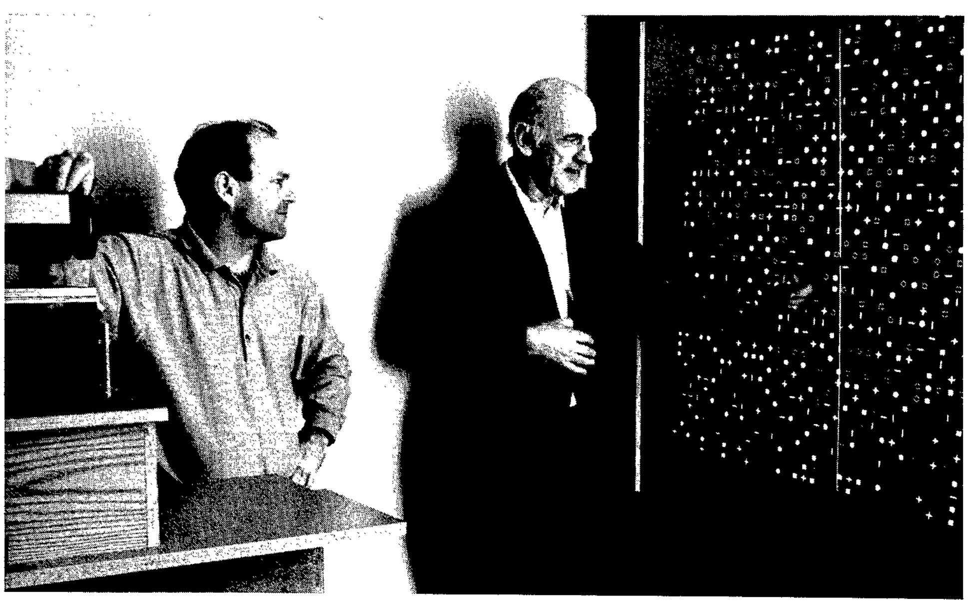


Figure 9. During a two-year exchange with a Canadian defense unit, Armstrong Laboratory's Dr. Byron Pierce collaborated on behavioral research examining the design and use of stereoscopic displays. He also conducted research on visual perception issues. The results of Dr. Pierce's work will be used to develop increasingly sophisticated and realistic flight simulators for rotary and fixed-wing aircraft. In Figure 9, Dr. Pierce (at left) and Dr. Ian Howard of the Institute for Space and Terrestrial Science study a display of visual stimuli used in one of their experiments.

Directorate of Chemistry and Life Sciences

Researcher Achieves Breakthrough in Target Discrimination Technology

Dr. Larry Wolff of the Johns Hopkins University Computer Science Department has developed the technology to visually discriminate between nonmetallic (dielectric) decoys and metallic (electric) targets using polarized vision. This technological breakthrough will enable Air Force aircraft to rapidly detect friendly forces concealed in foliage and identify specially marked landing and drop zones. It can also be used to "passively" (without emitting energy) identify the exact location of underground bunkers or tunnels "tagged" by ground forces. Wolff's work also holds promise for improved flight safety by allowing pilots to differentiate the horizon more clearly when flying over water or on hazy days.

When ambient light strikes and reflects off objects, different scattering patterns are created depending on the composition and shape of the object. Normal vision cannot distinguish between these different spectral patterns. Wolff's new technology uses a miniaturized scanning device to allow the human eye to distinguish these patterns. He used a nine volt camera battery to power a three-line scanning lens that can easily be placed in front of a pair of goggles or a reconnaissance camera. This device makes metallic targets appear in a glowing red-violet color. This miniaturized scanning lens technology employs "proprietary" modifications to existing computer chips. Additional research is required to achieve the enhanced speed associated with using a totally self-contained chip with software that could be tuned to perform in various polarization spectrums.

Lt. Col. Daniel Collins
Directorate of Chemistry and Life Sciences
(202) 767-5021, DSN 297-5021

Research Team Demonstrates Physical Exercise Shifts the Human Biological Clock

A research team led by Dr. Eve van Cauter at the University of Chicago demonstrated that three hours of nighttime exercise, starting as early as 2230 and ending as late as 1030, consistently shifts the human biological clock nearly an hour or the equivalent of one time zone. This physical activity is accompanied by a certain level of heightened mental alertness. The results of this research can be used to develop specific regimens of sleep and exercise for air crews on long flights to produce maximum alertness at critical times during the mission.

The van Cauter team's discovery grew from an ongoing investigation of the fundamental characteristics of non-photic control (any control not created by light including exercise) of the human circadian pacemaker. The results of this research can be used to design schedules of exposure to bright light, darkness and exercise. The schedules could accelerate air crews adaptation to "jet lag" and shift work without using drugs or isolating crews in specially designed units.

Studies of animals in the last ten years indicated that a diverse series of non-photic stimuli can affect the phase or period of the circadian pacemaker through neural pathways independent of light. Although diverse in nature, these non-photic "zeitgebers" appear to exert their effects though a common neural pathway involving increased physical activity or "arousal." Based on these findings, the van Cauter team initiated a systematic study of the potential zeitgeber effects of scheduled physical or mental activity on human circadian rhythms. The team studied 17 normal, healthy young men to determine whether a single episode of physical activity can induce rapid phase-shifts in human circadian rhythms. Their phase-shifts were measured on the day following timed exercise. The timing of the exercise was similar to that used in the animal studies, ranging from five hours before to four hours after the time of minimum body temperature. This nighttime exercise evidenced one to two-hour phase delays of both melatonin and other hormone rhythms. The size of the phase delays were smaller when the exercise was done in the latter part of the nighttime period and in the early morning hours.

Dr. Genevieve M. Haddad
Directorate of Chemistry and Life Sciences
(202) 767-5023, DSN 297-5023

New Software Company Based on AFOSR-Sponsored Research

Professor Michael Dewar of the University of Texas developed a novel approach to computational chemistry with long-term AFOSR support from 1965 to 1993. Professor Dewar's method allows the theoretical prediction of chemical reactions and reaction mechanisms to be used as practical adjuncts to experimental procedures. His method is much more user friendly than the conventional "ab-initio" method to predict reactions. It allows the Air Force, university researchers and chemical and pharmaceutical companies to better predict molecular structure and properties and optimize their chemical synthesis processes. This translates to better materials and lower production costs.

Several funding agencies rejected Dewar's proposals in the 1960s as too radical before he turned to AFOSR. During the long period he worked with AFOSR support, his semiempirical method, as it was named, gained wide acceptance and popularity throughout the defense, commercial and industrial communities. After Dewar's retirement in 1993, Professor Andrew Holder of the University of Missouri-Kansas City, began to build on Dewar's accomplishments to advance this technology with AFOSR support. With Dewar's urging, he created a company named Semichem to commercialize the software based on semiempirical computational chemistry. In the past three years, Semichem has produced several updated versions of the software under the name AMPAC with graphical user interface. Semichem sold more than 150 copies of the 1994 version of the software to government organizations, academic researchers and commercial enterprises. Many people are still using the last public domain version of AMPAC and other software companies have included Dewar's methods in their programs.

Dr. Frederick L. Hedberg
Directorate of Chemistry and Life Sciences
(202) 767-5024, DSN 297-5024

Plants Offer Potential to Cleanup and Dispose of Toxic Cadmium Residue

Dr. Rajesh Mehra, a biochemist at the University of California-Riverside, has discovered that certain plants can resist the toxic effects of cadmium due to the formation and sequestration of extremely high levels of cadmium sulfide crystallites inside cells. By understanding the biochemistry of how plants protect themselves from cadmium toxicity, researchers are taking the first step in learning how to use plants to cleanup and dispose of cadmium-polluted sites and waste streams. This white, ductile metal is extensively used by the U.S. Air Force as a critical ingredient in the construction, maintenance, and repair of aircraft.

Using a cadmium-resistant variant of the wild-type yeast strain of Candida glabrata, Dr. Mehra was able to show that enhanced resistance was not due to increases in concentrations of the metal-binding peptides called glutathione and phytochelatin nor to increases in their chain lengths. When chromatography and spectral analyses were applied, the presence of cadmium sulfide crystallites in both the wild-type and resistant strains were observed and later confirmed by chemical analyses. The resistant strain, however, contained cadmium sulfide crystallites that were more uniform in size and much larger, accounting for their 10-fold higher luminescent intensities. Kinetic studies using differential interference microscopy indicated that the crystallites were being formed in the cytosolic compartment of the cell and slowly accumulating inside membrane-bound storage vesicles called vacuoles.

Dr. Mehra is now pursuing the possibility that cadmium is stimulating sulfate reduction by altering expression of a gene whose product regulates the sulfate reduction pathway. Understanding the biochemical and molecular pathways which cells use to protect themselves from cadmium toxicity will be useful in developing advanced environmental biotechnology cleanup and waste disposal methods.

Dr. Walter J. Kozumbo
Directorate of Chemistry and Life Sciences
(202) 767-4281, DSN 297-4281

Fluorination Improves Heat Stability of Diamond-Film Lubricant

University of Pittsburgh chemists John Yates Jr. and V. S. Smentkowski have developed a new method for fluorinating diamond film surfaces with heat-stable carbon-fluorine (C-F) bonds up to 1500°K. The Air Force uses diamond films as solid-lubricant coatings for such high-temperature applications as bearings in the engines of missiles and aircraft. The procedure also is useful for enhancing diamond oxidation resistance from atomic or molecular oxygen exposure to prevent loss from corrosion-like effects.

The new facile method involves perfluoroalkyl iodide molecules like CF_3I and C_4F_9I. Radiation infusion activates the molecules, producing alkyl radicals that anchor themselves to the diamond surface. The molecules decompose on the diamond surface by cleaving the weak C-I bond, then anchor perfluoroalkyl groups to the surface at temperatures below room temperature. From the C_4F_9I molecule, Drs. Yates and Smentkowski detached CF_2 and CF_3 species that decompose at mild temperatures to make surface C-F bonds.

An important finding is that perfluoroalkyl iodides generate much more surface coverage for fluorine than do older methods that use active fluorine sources like plasmas or atomic beams. This lets researchers fluorinate larger portions of the diamond surface using a simple reaction that proceeds under mild conditions and produces thermally stable C-F bonds. The University of Pittsburgh has applied for a patent on the process.

Capt. Hugh C. DeLong
Directorate of Chemistry and Life Sciences
(202) 767-7761, DSN 297-7761

Ultrasensitive Sensors Assist COIL Laser Development

AFOSR-sponsored research has led to the development of ultrasensitive sensors to detect minute quantities of water vapor and other gases. Laser researchers at Phillips Laboratory (Kirtland AFB, Albuquerque) and ABL contractors are now using these sensors to improve the output power and efficiency of the Chemical Oxygen Iodine Laser (COIL), selected for use in the Airborne Laser (ABL) Demonstrator Program.

The sensors monitor the absorption of light emitted from compact diode lasers that are tuned to the wavelength of the atomic or molecular transition of interest. A sensor for iodine atoms, developed by Prof. Stephen Leone at the University of Colorado, has led to the improved positioning of the COIL laser resonator, resulting in a 20 percent increase in COIL output power and efficiency. A sensor for water vapor, developed by Dr. Steven Davis at Physical Sciences, Inc., is optimizing the COIL configuration to minimize water vapor, a gas that degrades laser performance.

Many other applications are being demonstrated for the ultrasensitive sensors, including the manufacture of advanced carbon-carbon composites and for controlling performance in jet engines. The Science Applications International Corp. (SAIC, Santa Ana, Calif.) has used Dr. Davis' water-vapor sensor to control process parameters in the extremely harsh conditions (700°C) of a processing furnace to monitor the evolution of water vapor during the carbonization cycle of carbon-carbon composites. The sensor cuts production time 10 percent and produces carbon-carbon composites with fewer defects.

Dr. Davis has also developed oxygen-molecule sensors that are being used in COIL development. NASA is using the sensors to measure mass flows for controlling performance of jet engines.

Added note: AFOSR-sponsored research has played a vital role in the initiation and development of the COIL laser. In the 1960s, the first iodine atom laser was demonstrated in research at the University of California, Berkeley. AFOSR support also contributed to the development and scale-up of the first chemical oxygen iodine laser at the Air Force Weapons Laboratory (now the Phillips Laboratory) at Kirtland AFB.

Dr. Michael R. Berman
Directorate of Chemistry and Life Sciences
202-767-4963, DSN 297-4963

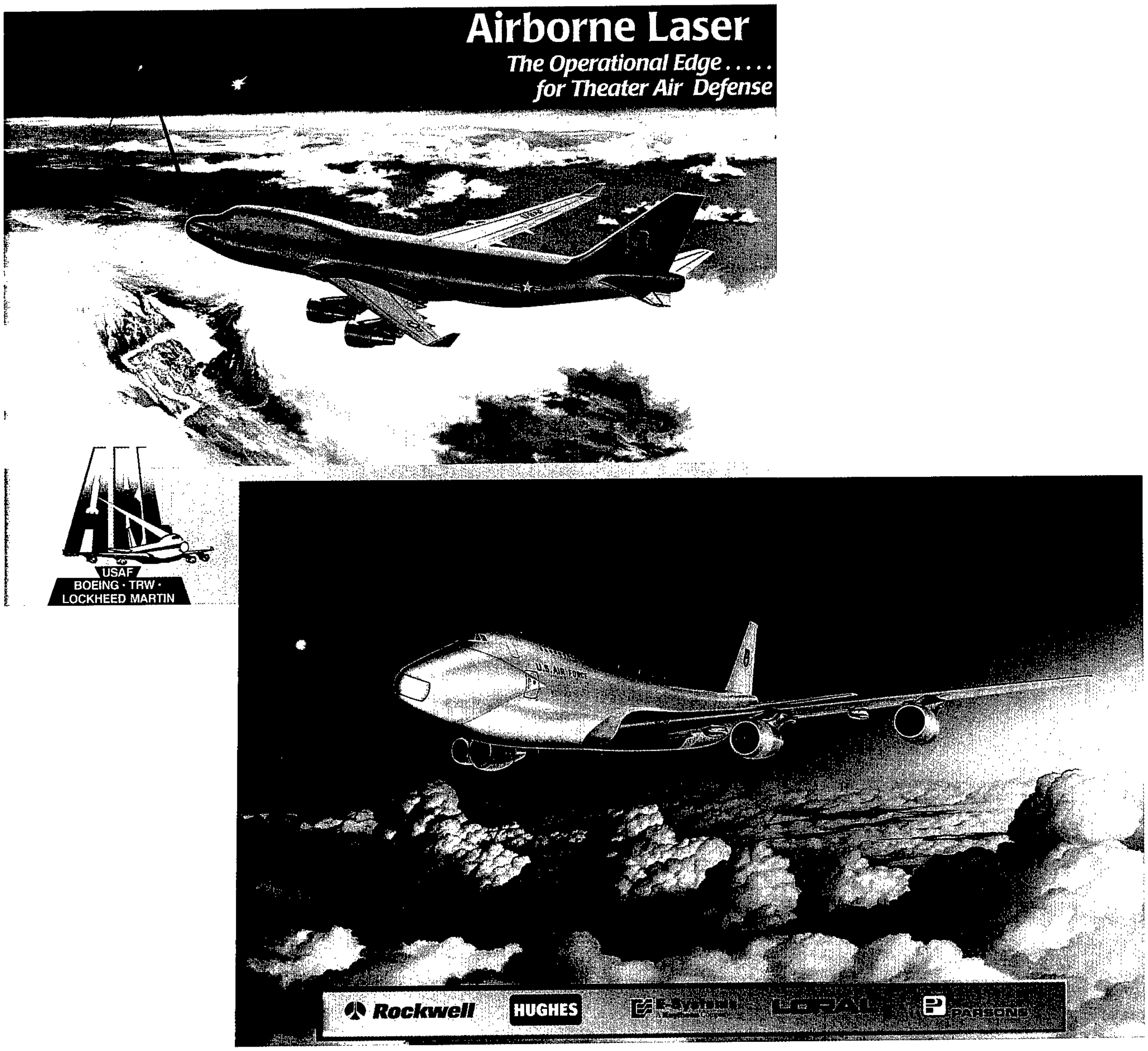


Figure 10. The Airborne Laser (ABL) Demonstrator Program is an Air Force Advanced Technology Demonstration program to develop and demonstrate the necessary technologies to acquire, track, and destroy theater ballistic missiles during the boost phase. Ultra-sensitive sensors, developed from AFOSR-sponsored research, are being used in the competing system demonstrators to improve laser power and efficiency.

AFOSR Funds New Method for Making Electro-Optical Crystals

A 3.5-year AFOSR-sponsored research effort has produced an atmospheric-pressure growth method for inorganic crystal structures. Before now, only very high pressures could produce these structures. The crystals have potential use as semiconductor materials for electro-optical Air Force computing, sensing and display applications.

Prof. Patricia Bianconi at Penn State University devised a way to mimic the highly controlled crystal growth in shellfish after investigating the literature on materials and mechanisms associated with the process. The research, which she directed, is based on the ability of certain shellfish to grow shells using a crystal structure of calcium carbonate that can't be obtained with conventional ambient-pressure crystallization methods.

In place of the biomembrane system that controls crystal growth in shellfish, Prof. Bianconi's group substituted an ethylene oxide polymer to provide complexation and control diffusion for the inorganic reagents. They also used a surfactant to promote crystallization and nucleation sites. With this biomimetic synthesis system, they produced cadmium sulfide and lead sulfide crystal structures that are ordinarily fabricated only at 20,000 to 70,000 atmospheres of pressure.

Prof. Bianconi will extend this generic approach to other high-pressure-phase inorganic crystal compositions with ferroelectric and structural applications. She also intends to learn more about the mechanism that causes this localized, very-high-pressure environment at nanoscale dimensions.

During the course of this research, Prof. Bianconi received three awards for her performance as a research scientist and teacher: the Camille and Henry Dreyfuss Teacher/Scholar Award, a Sloan Foundation Fellowship, and a Beckman Foundation Young Investigator Award. She leveraged her AFOSR support by applying supplementary funding from the awards to this effort.

Dr. Frederick L. Hedberg
Directorate of Chemistry and Life Sciences
202-767-5024, DSN 297-5024

Scientists Characterize a Candidate Fluid for Turbine Engine Oils

An interdisciplinary basic research team at Wright Laboratory (Wright-Patterson AFB, Ohio) has characterized a lubricant, leading to its selection as a preliminary fluid for use in the Phase II gas turbine oil demonstration for the Integrated High-Performance Turbine Engine Technology Program. Their work on a commercial linear perfluoropolyalkylether (PFPAE) fluid was based on the team's new understanding of surface changes that occur when lubricant and metal interact.

PFPAE fluids are now considered the most promising base fluids for lubricating high-temperature gas-turbine engines because they're stable over a wide temperature range, they're chemically inert, and they stay liquid over a range of low temperatures.

Initially the team, led by Wright Lab tribologist Dr. Kent Eisentraut, used computational chemistry, mass spectrometry and supercritical fluid chromatography to examine the relation between chemical structure and the properties of model compounds. They later extended their studies to very-high-molecular-weight commercial PFPAE fluids.

Boundary lubrication studies using steel samples and linear PFPAE fluids at different humidity levels showed that higher humidity causes a protective lubricous thin film to form on the metal surface. An earlier, separate experiment showed that coating steel coupons with titanium nitride curbed precipitate formation and significantly reduced corrosion and fluid degradation. Extending the study to more stable PFPAE fluids, the researchers used molecular modeling/computational chemistry and thermal and catalytic degradation studies of PFPAE model compounds they had synthesized to extensively characterize commercial PFPAE fluids. They found linear PFPAE compounds to be most stable and the best choice for testing.

The team prepared a series of metal complexes soluble in PFPAE fluids as standards for determining trace metals. They also developed a sensitive analytical method for detecting trace metals in PFPAE fluids. This allows them to use spectrometric oil analysis to detect wear in these fluids.

Capt. Hugh C. DeLong
Directorate of Chemistry and Life Sciences
202-767-7761, DSN 297-7761

Directorate of Mathematics and Geosciences

Scientists Develop New Method for Automatic Control System Design

Professor Stephen Boyd of Stanford University, in collaboration with several other AFOSR-sponsored researchers including John Doyle (Cal Tech) and Michael Safonov (USC), has developed a completely new approach to control system analysis and design. The method will allow the application of advanced and powerful techniques to a vast number of practical control problems involving nonlinearity and model uncertainty. For example, changing mission requirements often cause the Air Force to make substantial reconfigurations of aircraft and missiles which in turn require major changes in control system design. When implemented in automatic control system design software, the new method will provide an efficient and reliable means to shorten the labor-intensive control system design cycle for these reconfigurations.

One of the researchers' innovations was to show how a number of difficult fundamental control problems can be formulated as mathematical optimization problems involving matrix inequalities. These nonlinear, large-scale optimization problems can appear difficult and generally do not have

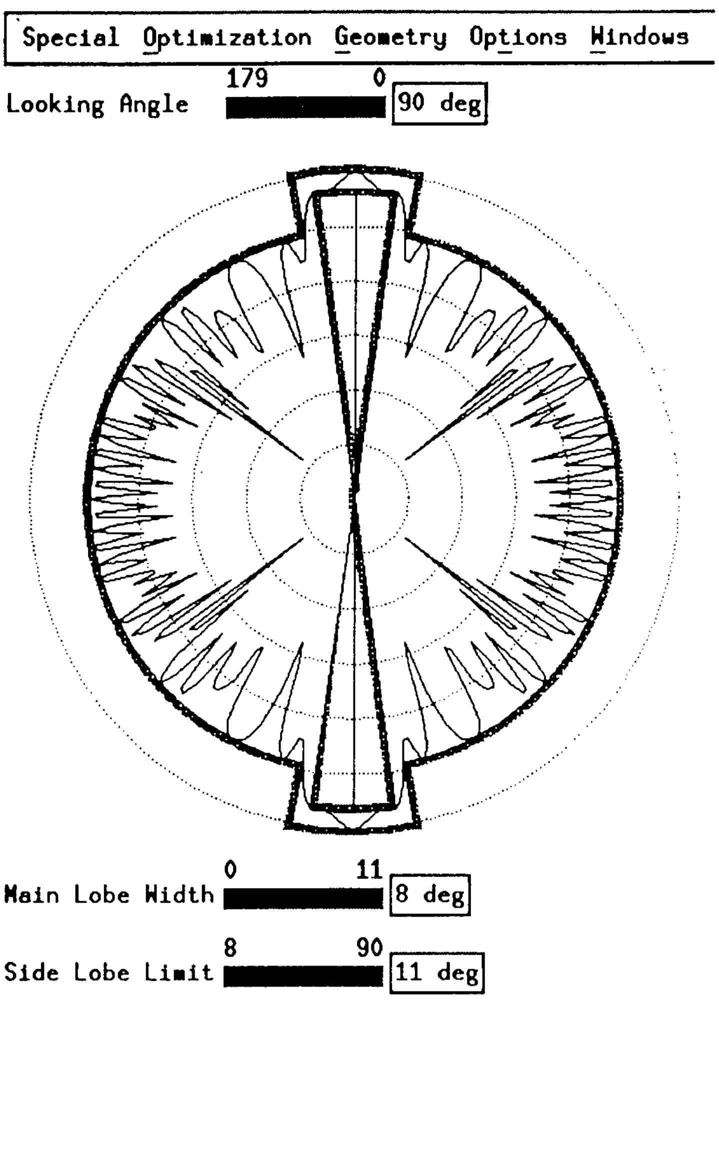


Figure 11. Scientists at Stanford University, Cal Tech, and the University of Southern California have developed a new mathematical method that can be applied to complex Air Force control system analysis and design problems. The method is particularly suited to computer-aided control system design because of its computational efficiency and its applicability to a wide variety of practical problems. Figure 11 shows the application of the method, using computer-aided design, to a problem involving phased-array antennas. For small and medium-sized problems, the optimization is so fast that the final design appears to track in real time, as the designer graphically varies the specifications or array geometry.

analytical solutions. In a major breakthrough, the researchers succeeded in developing efficient interior-point algorithms to solve these problems numerically. Boyd and his colleagues were able to show that by exploiting the structure of the control problems, great efficiencies could be obtained. Their methods can solve problems involving thousands of variables and tens of thousands of constraints in a few minutes on individual workstations.

Several commercial computer-assisted control design packages based on this method are under development. The method has already been used with great success in several challenging, experimental preliminary design studies including the control of highly-maneuverable air-to-air missiles and the control of advanced, semiconductor manufacturing equipment. Because of its great computational efficiency and the wide variety of practical problems that can be addressed, the method is especially well-suited for computer-aided control system design. The matrix inequality solution algorithms can be readily embedded in computer-aided design tools that incorporate a natural user-interface for problem specification. The control problem is automatically translated into the appropriate matrix inequality problem which is then solved using efficient interior point methods.

Dr. Marc Jacobs
Directorate of Mathematics and Geosciences
(202) 767-5027, DSN 297-5027

Search Strategy Advances Improve Scheduling in Aircraft Manufacturing

Dr. James Crawford of the Computational Intelligence Research Laboratory (CIRL) at the University of Oregon has developed an advanced scheduling algorithm based on newly discovered search strategies. When it was applied to an actual aircraft manufacturing scheduling problem at McDonnell Douglas, the result was an increase in efficiency and considerable savings. This same algorithm could also result in considerable savings for the manufacture of Air Force aircraft.

Crawford demonstrated his algorithm on a task at McDonnell Douglas to schedule the steps involved in the simultaneous manufacture of three aircraft. Crawford's algorithm was able to produce a 36-day schedule for the tasks involved while the best scheduler at McDonnell Douglas produced a 38-day schedule. Since each day of this schedule costs McDonnell Douglas $250,000, the application of Crawford's algorithm saved the company $500,000.

Building each group of the three aircraft in the McDonnell Douglas project involves 600 tasks, each of which breaks down into as many as ten sub-tasks requiring one of 11 resources for some period of time. There is also a set of constraints that has to be satisfied. For example, a simple precedence constraint forbids painting a wing before it is assembled and a capacity constraint prevents too many sub-tasks from drawing on the same resource. Determining a schedule of minimum length that obeys a given set of constraints is, for all practical purposes, not computable. However, Crawford's development can produce schedules significantly shorter than those currently in use.

Traditional schedulers for such tasks as the one at McDonnell Douglas build a network of the precedence relations required to hold and find the longest path in the network, the "critical path."

Next, they address all other constraints in turn and typically, each such constraint increases the length of the schedule. Crawford's algorithm adds a search method from the domain of artificial intelligence to the more traditional critical path technique in order to perform faster and more efficient searches. Even greater savings are expected with further improvement of his algorithm.

Dr. Abraham Waksman
Directorate of Mathematics and Geosciences
(202) 767-7903, DSN 297-7903

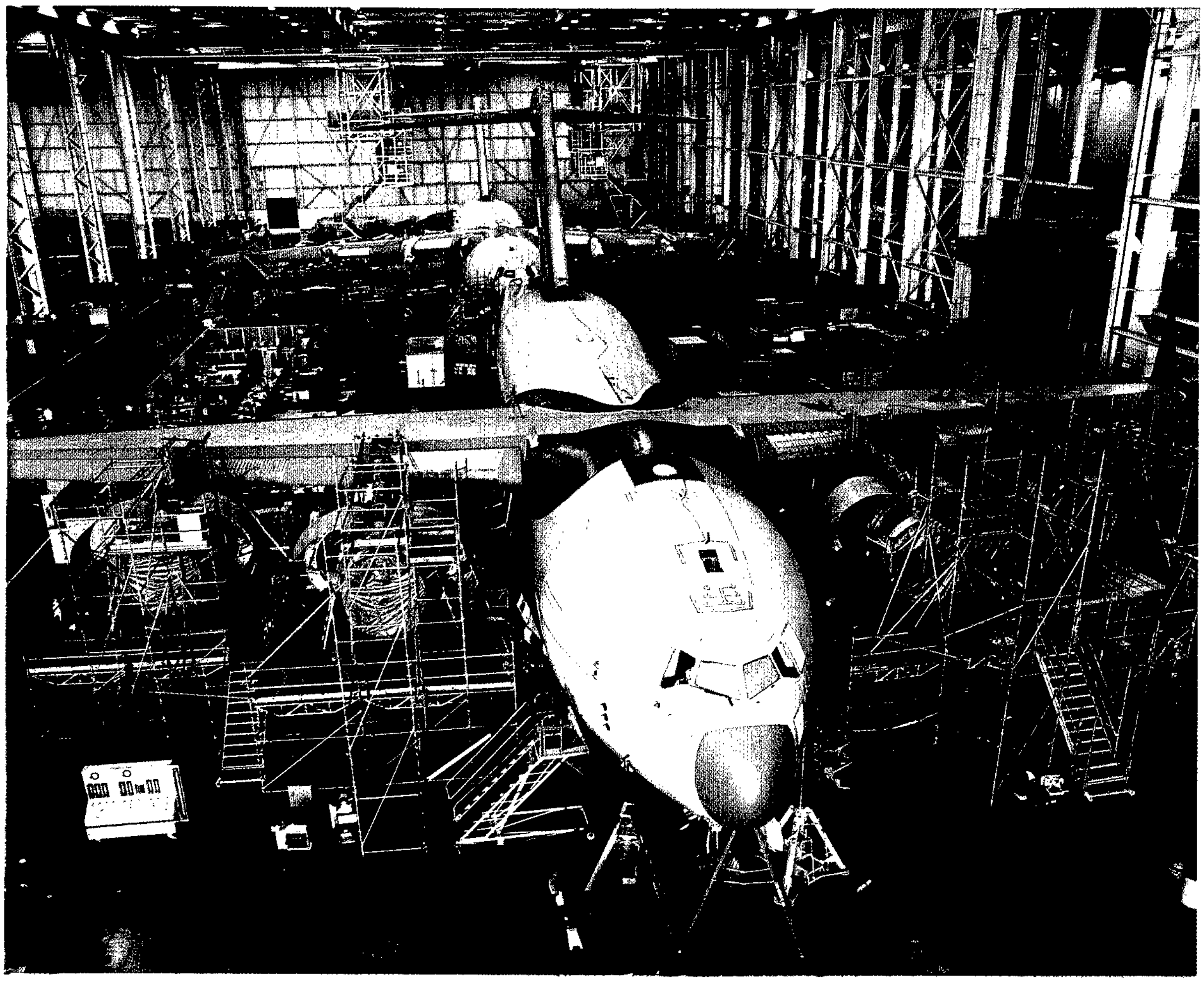


Figure 12. A University of Oregon researcher has developed an advanced scheduling algorithm based on newly discovered search strategies. When applied to aircraft manufacturing schedules, it results in increased efficiency and significant cost savings. The method was tested successfully on the tasks involved in simultaneously manufacturing three aircraft. Figure 12 shows two U.S. Air Force C-17 Globemaster IIIs in final assembly at the McDonnell Douglas facility in Long Beach, Calif.

Use of Computational Fluid Dynamics Optimizes C-17 Paratroop Deployment

Professor Marsha Berger of New York University's Courant Institute of Mathematical Sciences, and Captain Mike Aftosmis, Wright Laboratory, have employed state-of-the-art computational fluid dynamics (CFD) to optimize C-17 paratroop deployment. These results demonstrate that advanced CFD methods can quickly provide aircraft flow characterizations that are low cost and accurate. Such flow characterizations can be used to efficiently refine aircraft flight parameters to meet mission requirements.

Professor Berger and Captain Aftosmis successfully performed Euler calculations on an adaptively refined Cartesian grid containing nearly two million nodes. Completed only 20 days after the aircraft geometry was initially acquired, these computations showed that air deflected by the wing flap and vortices generated by the landing gear pod severely disrupted flow near the aircraft doors. However, computation utility went well beyond qualitative problem identification. High solution accuracy and rapid turnaround time enabled quantitative optimization of flight parameters for paratroop deployment. Small adjustments to aircraft angle-of-attack and flight speed during paratroop deployment significantly displaced disruptive flows originating at the wing flap and gear pod. This, in turn, substantially improved air flow quality near the doors and greatly enhanced paratroop deployment.

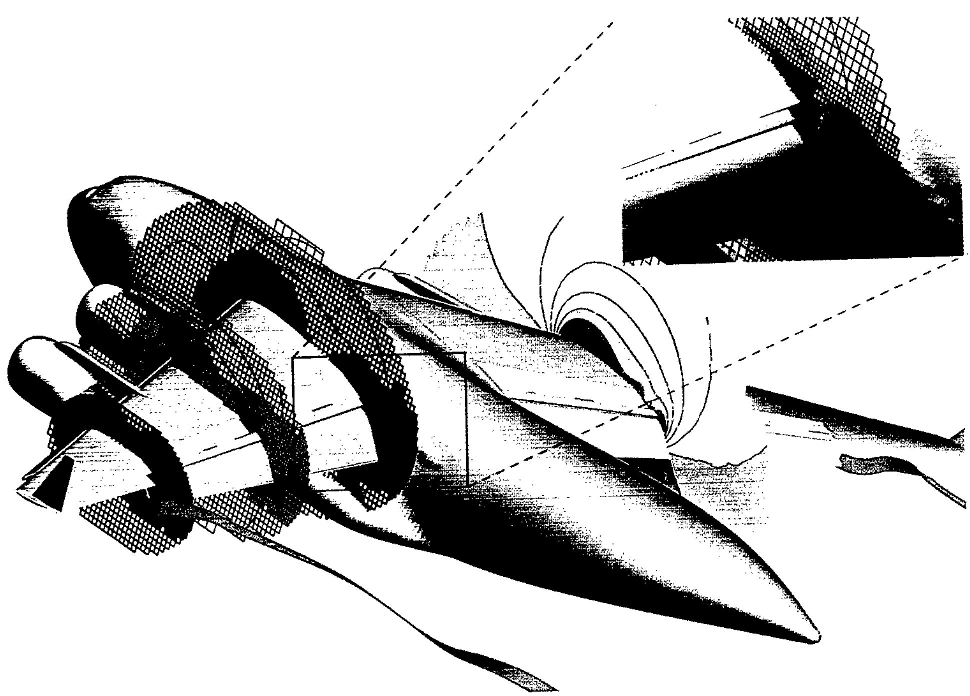


Figure 13. Researchers at Wright Laboratory and New York University have used advanced computational fluid dynamics (CFD) to provide low-cost and accurate aircraft flow characterizations. These will allow small adjustments to aircraft angle-of-attack and flight speed, which will improve air flow quality near the aircraft doors, thus greatly enhancing paratroop deployment. Figure 13 illustrates the researchers' use of adaptively refined Cartesian meshing to characterize air flow around C-17 wings. The mesh contains 1.65 million cells and 9 levels of refinement. On the near wing, the mesh is shown at three span locations. On the far wing, pressure contours obtained from the computation are shown at one span location.

Over the last decade, AFOSR has supported Professor Berger's research in adaptively refined Cartesian grids. Adaptive refinement concentrates computational power in the aircraft flow field where the dominant physical interactions occur. Cartesian grids facilitate discretization of complex aircraft surface geometries. Without this technology, existing computational resources would be insufficient to resolve crucial physical effects in aircraft flow fields.

Major Scott J. Schreck
Directorate of Mathematics and Geosciences
(202) 767-7902, DSN 297-7902

Neural Nets Speed Deployment Planning

An applied mathematics and systems scientist at Washington University developed a computer aid to help analysts at the Headquarters Air Mobility Command (AMC) operate at stable levels despite staff reductions. AMC uses a large simulation model, the Mobility Analysis and Support System (MASS) to plan and schedule supply movements.

Prof. Ervin Rodin, director of W.U.'s Center for Optimization and Semantic Control, developed neural networks that recognize common supply movement patterns. They also optimally process time-phased force deployment documents (TPFDDs) that specify the move requirements. His goal is to teach neural networks to develop a stable set of example networks so AMC can analyze its transportation fleet's capabilities and requirements. Dr. Rodin trained and validated the networks on declassified TPFDD data from Operation Just Cause in Panama. His predictions are now 98 percent accurate.

The neural network recognizes patterns to ease the complex allocation and assignment process. Dr. Rodin is extending the research to incorporate uncertainties inherent in the planning process. Some variables crucial to accurate scheduling - like the maximum number of aircraft on the ground at a base (MOG) - are only roughly known. Dr. Rodin sent four students to AMC this past summer for hands-on experience in military transport routing and scheduling. HQ's AMC command analysis group is providing assistance to Dr. Rodin for additional research that addresses MOG-related variables.

Dr. Neal Glassman
Directorate of Mathematics and Geosciences
202-767-5026, DSN 297-5026

Smart Radar Detection Boosts Electronic Countermeasures

An electrical engineer at Syracuse University is using an expert system to computationally analyze and reduce background clutter that impairs radar detection and surveillance. Dr. Pramod Varshney, university colleagues, and researchers at the Air Force's Rome Laboratory (Rome, N.Y.) designed ways to statistically estimate critical characteristics of background clutter. Now radar operators can choose the best Constant False Alarm Rate (CFAR) algorithm for their situation.

Radar's false-alarm rate for detecting targets and intruders has always been high. If hostile countermeasures or another source of noisy electromagnetics interrupted the process, the radar's detection capability tended to plunge. The CFAR algorithm solves this problem. A more advanced approach would use several CFAR processors and weight the answers to draw a conclusion. The next step is

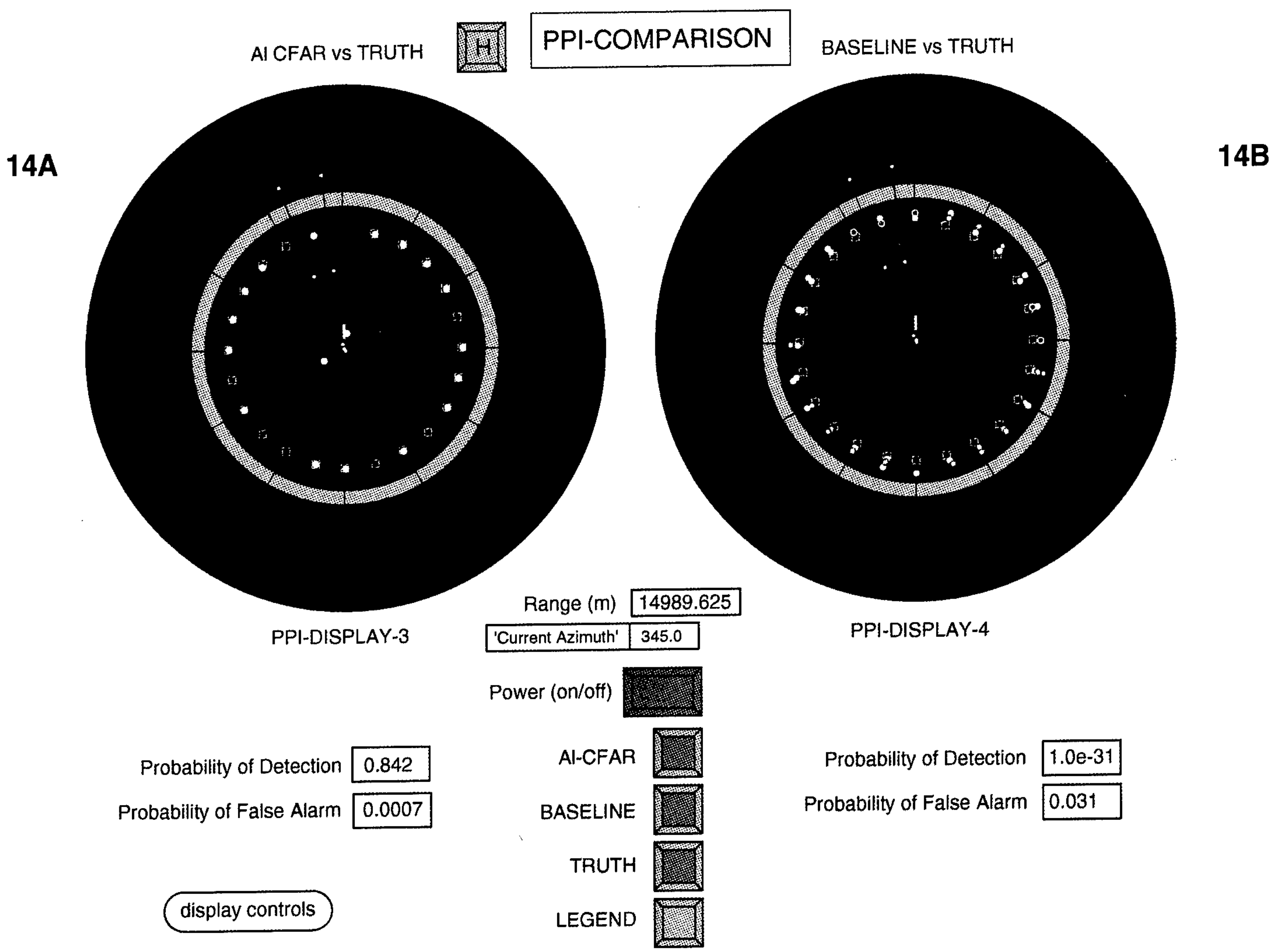


Figure 14. A Syracuse University engineer has successfully used an expert system to computationally analyze and reduce the background clutter that impairs radar detection and surveillance. Figures 14A and 14B illustrate the use of the expert system on a Plane Position Indicator (PPI). The blue squares represent targets giving returns at different strengths. The "tan"-colored ring depicts a region of exponentially-distributed "clutter." Dealing effectively with clutter is the challenge for target detectors. In Figure 14A, the perceived targets line up in the center of the blue squares, showing how intelligent sensing of the clutter phenomenon and adaptive use of "Order Statistic" system detects more targets with a lower rate of false alarm than does the conventional method. Figure 14B shows contrasting results with conventional detection. In this method, the clutter region gives numerous detections outside the blue square and near the clutter edge. This means that perceived targets are placed incorrectly (false alarms).

to use the CFAR expert system with RF and non-RF sensors. An intelligent suite of CFAR processors could tell which approach is right for conditions. In such environments, algorithms and threshold parameters that say yes or no to detection must be intelligently adaptable.

Col. Ed Taylor, director of the E-3 SPO, Airborne Early Warning and Control System (AWACS, Hanscom AFB), says that based on results from AWACS data, the expert system CFAR detector is ready for an early upgrade into the AWACS signal-processing configuration. AFOSR has supported Dr. Varshney for more than a decade. Since the mid-1980s he has collaborated with Dr. Vincent Vannicola of Rome Lab's Surveillance and Signal Processing group. The Rome Lab has integrated Dr. Varshney's techniques into a versatile software system.

Dr. Jon Sjogren
Directorate of Mathematics and Geosciences
202-767-4940, DSN 297-4940

New Active Disturbance Rejection Technology Improves Airborne Laser Aim

A group of Air Force and university control scientists has developed a new adaptive feed-forward vibration-cancellation methodology. This new adaptive control technology could sharply improve the performance of a wide variety of Air Force systems — ranging from satellites to engines to aircraft structures — which require the active control of vibrations for effective operation.

Basic researchers Don Washburn and Rick Walter of the Air Force Phillips Laboratory (Albuquerque), Fred Boelitz of Aerospace Corp., and Steve Gibson of UCLA recently demonstrated the effectiveness of the control technology during a series of airborne experiments on a C-135 aircraft as an adjunct to an airborne laser data-collection experiment, ABLE ACE.

The Phillips Lab is already applying the concepts demonstrated in these experiments in an experimental program to cancel acoustic noise in precision systems. The direct pointing improvement and acoustic noise cancellation were inspired by and apply directly to the Air Force's high priority Airborne Laser System (ABL). Col. Richard D. Tebay, director of the ABL program office, cited the researchers' excellent technical work and vision in meeting this technical need. "This effort is an excellent example of how AFOSR basic research efforts can directly insure the success of advanced Air Force and DoD systems."

The most novel feature of the new adaptive methods was the adaptive least-squares lattice filter used for adaptive identification of the feedforward gains. This lattice filter and the new algorithm based on it were developed at UCLA under AFOSR sponsorship. The main advantages of the least-squares lattice over older methods (such as least mean squares filters) in adaptive vibration cancellation methodologies include faster convergence (and adaptation), numerical stability for large-order and multichannel filters, and inherently parallel computing architectures.

The recent experiments represent several advances in active-vibration suppression and noise cancellation. Adaptive noise cancellation methods have been applied to stationary disturbance rejection, but the ABLE ACE experiments show the new methods improve precision tracking in a difficult but realistic airborne environment dominated by nonstationary disturbances. The combination of nonstationary and large track-error components uncorrelated with noise references makes adaptive identification of optimal filter gains particularly challenging. In these experiments, the aeroelastic interaction of atmospheric turbulence and the C-135 airframe produced disturbances that were highly nonstationary.

Dr. Marc Jacobs
Directorate of Mathematics and Geosciences
202 767-5027, DSN 297-5027

Radiation Belt Proton Model May Help Conserve USAF Satellites

A university - Air Force laboratory collaboration has produced a model of stimulated radiation belt precipitation that could help protect Air Force satellites, the main tools for C3I activities in space. The model may be used to protect satellites from energetic protons that disrupt electronic signals of all kinds in spacecraft operating between low Earth and geosynchronous orbit. Energetic radiation belt particles are a major hazard to Air Force space systems that operate in orbits between 1.6 and 6 earth radii. These charged atomic particles, particularly protons, cause a variety of problems including spacecraft charging and single-event upsets in semiconductors.

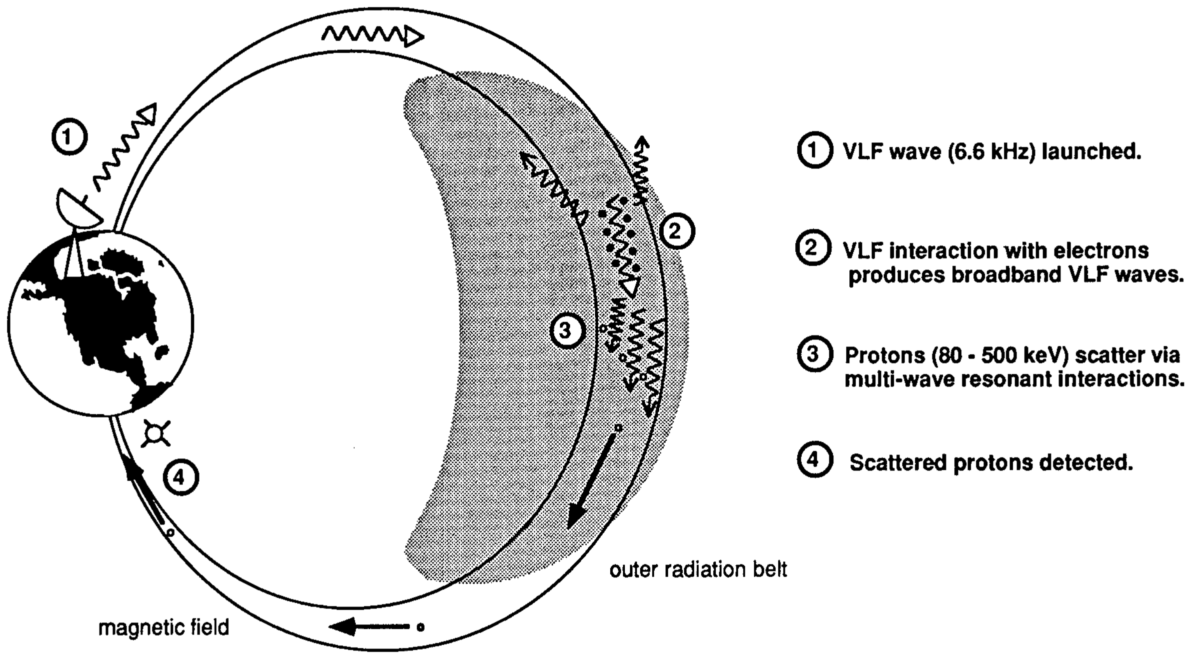
Evidence for the protons' existence was first reported by Russian Very Low Frequency (VLF) experimenters. They discovered that injecting VLF waves from ground-based antennas at high latitudes can stimulate proton precipitation from outer regions of the radiation belts.

Air Force interest includes techniques for selectively depleting the damaging proton populations to protect USAF resources or for enhancing them to destroy adversarial resources. Physicists Dr. Elena Villalon at Northeastern University and Dr. William J. Burke at the Air Force's Phillips Laboratory (Hanscom AFB, Mass.) developed a theoretical model to explain this phenomenon. The VLF waves interact with radiation belt electrons and become amplified and broadened in frequency. These waves then interact with protons near the equator through a sequence of nonlinear resonance interactions that alter proton velocities along the magnetic field and ultimately scatter them into the ionosphere. Previous researchers had focused on studying single-wave interactions that failed to obtain these results.

Drs. Villalon and Burke plan to incorporate this model - developed by analyzing the results of a small number of experiments - into complex kinetic radiation-belt codes that can be used to explore the possibility of modifying the radiation belt to defend satellites and missiles.

Dr. Henry R. Radoski
Directorate of Mathematics and Geosciences
202-767-7901, DSN 297-7901

MODEL OF STIMULATED RADIATION BELT PROTON PRECIPITATION



- **Experiments show ground launched VLF waves precipitate protons.**
- **New precipitation model quantifies nonlinear interaction mechanism.**

Figure 15. Physicists at Phillips Laboratory and Northeastern University have developed a theoretical model to explain the stimulation of proton precipitation from outer regions of the radiation belts, which can be caused by very low frequency (VLF) waves from ground-based antennas. These energetic protons disrupt signals in spacecraft operating between low Earth and geosynchronous orbit. Understanding how these protons can be stimulated allows the Air Force to develop methods for depleting them or enhancing them to destroy adversarial resources. Figure 15 summarizes the model of stimulated radiation belt proton precipitation.

Multidisciplinary New Nonlinear Control Concept Expands Jet Engine Operating Envelope

Professor Eyad H. Abed and his research group at the University of Maryland, College Park, have introduced a new nonlinear control design which will permit the operation of an axial flow compressor up to and beyond the stall limit. This research provides a key step toward the integrated control of jet engine aerodynamic and combustion instabilities which will lead to lighter engines with greatly improved performance characteristics for use in future military and civilian aircraft.

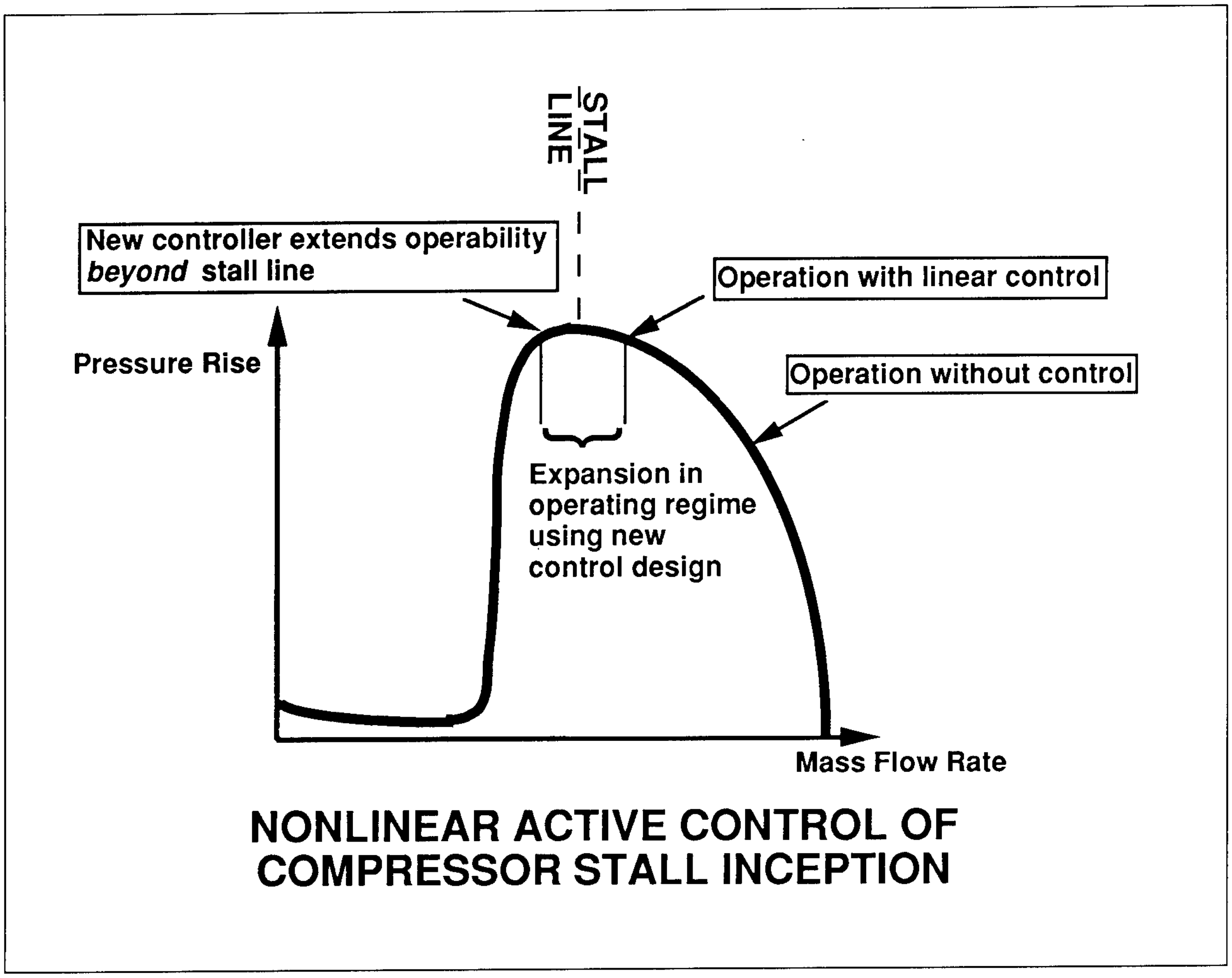


Figure 16. A research group at the University of Maryland, College Park, has developed a new nonlinear control design that will permit axial flow compressors to operate up to and beyond the stall limit. This may lead to the design of lighter jet engines with greatly improved performance capabilities.. Figure 16 illustrates the improvement possible with the new nonlinear control design, as shown by the bracket underneath the operation line and by the arrow to the left of the dotted stall line.

Linear methods cannot be used to stabilize the system on the stall boundary using practical actuation methods. The new design concept discovered by Abed's team uses bifurcation theory and other nonlinear analysis tools to give a practical characterization of the family of smooth nonlinear feedback control laws which result in a supercritical bifurcation (in simplified terms this means the new robust feedback controller causes a nearby stable operating condition to emerge). This work takes advantage of the compression system model developed and refined earlier by Edward Greitzer at MIT (AFOSR-sponsored) and Frank Moore at Cornell. Abed's new nonlinear control research motivated related work by Dr. Carl Nett and his group at Georgia Tech. Nett's group provided experimental validation of the concept at low speeds and pointed out key deficiencies at high speeds representative of industrial compressor designs. Dr. Nett subsequently moved to the United Technologies Research Center (UTRC) where the work is being continued. UTRC researchers have succeeded in modifying the original concept for use at high speeds and have filed a patent application on the modified approach.

Axial flow compressors control the pressure ratio and mass flow of most large aircraft engines. Operation of these compressors near their maximum pressure ratios can cause two types of aerodynamic instability: surge and rotating stall. The desirability of operating at maximum pressure ratio has stimulated several investigations into active control schemes that "quench" these instabilities. The combined efforts of the Maryland, MIT, Georgia Tech and UTRC groups has resulted in a new nonlinear approach that is proving effective in theory and practice. In addition to jet engines, the concept has potential uses in gas turbines in chemical plants and electrical power plants.

Dr. Marc Jacobs
Directorate of Mathematics and Geosciences
(202) 767-5027, DSN 297-5027

Dr. James McMichael
Directorate of Aerospace and Materials Sciences
(202) 767-4936, DSN 297-4936

New Material Improves Efficiency of High Bandwidth Optical Modulator

A University of California (UCLA) electrical engineer has used a new polymer material developed by two University of Southern California (USC) professors to demonstrate an optical modulator that operates at bandwidths much higher than previously possible. The researchers, all supported by AFOSR, created a new material processing technique that improves the efficiency of ultrahigh-frequency modulators by twofold.

Prof. Harold R. Fetterman's demonstration holds great promise for high-capacity communication channels critical to future Air Force C4I systems. The modulator can also be used to more clearly transmit microwave and millimeter-wave signals on optical carriers. New microwave applications stemming from the demonstration include remote siting of wideband radar antennas and advanced control systems like those needed in conformal phased-array radar for military aircraft.

To develop the new modulator, Drs. Larry Dalton and William Steier at USC integrated a novel optical polymer modulator material into a specially designed millimeter wave transmission line, obtaining measured bandwidths up to 60 Ghz, with higher bandwidths possible. The new material and processing technique were a breakthrough for Drs. Dalton and Steier, who discovered that using laser-assisted poling with electro-optical molecules can boost the efficiency of ultrahigh-frequency modulators more than twofold.

The discovery led to a change in the choice of chemistry that can undergo laser-induced poling for ultrahigh-frequency modulator materials. Such modulators need polymers whose refractive index changes in an external electric field. The size of the effect is proportional to the poling process's alignment of electro-optical molecules. Laser-assisted poling orients the molecules using direct-current field poling and laser-induced poling.

Dr. Dalton's work holds great promise for an array of microwave and millimeter wave applications. Dr. Fetterman's wideband modulator research is part of a broader program in innovative uses of light to generate, control and distribute millimeter wave signals. AFOSR has funded both projects for 10 years.

Dr. Howard Schlossberg
Directorate of Physics and Electronics
202-767-4906, DSN 297-4906

Dr. Charles Y-C Lee
Directorate of Chemistry and Life Sciences
202-767-5022, DSN 297-5022

New Thin Films Augment High-Speed Communication Nets

A Princeton University research team led by Prof. Stephen Forrest discovered a new way to grow large-area nonlinear optical crystalline thin films of organic salts. Organic Vapor Phase Deposition (OVPD) holds great promise for advanced optical devices with large organic-salt-based NLO waveguide structures for Air Force advanced high-speed communication networks and signal processing technology.

Because organic salts have large optical nonlinearity, waveguide devices based on them have high performance efficiency. But single-crystal salts don't easily form large-area thin films, hindering the process of turning them into waveguide structures. Prof. Forrest, director of Princeton's Advanced Technology Center for Photonics and Optoelectronics Materials, is the first to successfully deposit an organic salt—a two component molecular system of cations and anions. Earlier tries failed because deposition calls for equal deposition rates for both components, whose evaporation rates often differ.

OVPD is similar to vapor phase epitaxy or MNOCVD used to grow III-V compound semiconductors, a technique that AFOSR's Directorate of Physics has supported for five years. In OVPD, carefully selected volatile neutral organic precursors are combined in a hot-wall reactor zone to form an organic salt. The component with the lowest vapor pressure is evaporated with a controlled-temperature crucible.

An inert carrier gas transports the more volatile component. The resulting salt is deposited on a temperature-controlled substrate, a carrier gas removes reaction byproduct. By varying crucible, reaction zone, substrate and gas-flow rate temperatures, researchers use this technique to control film composition, purity and growth rates.

Maj. Michael Prairie
Directorate of Physics and Electronics
202-767-4931, DSN 297-4931

Dr. Charles Y-C Lee
Directorate of Chemistry and Life Sciences
202-767-5022, DSN 297-5022

Recognition of AFOSR Researchers

Optics Scientist Receives Frederick Ives Medal

Professor Herman Haus of the Massachusetts Institute of Technology, an AFOSR principal investigator in the Photonic Sciences program for 12 years, was recently awarded the Frederick Ives Medal by the Optical Society of America. The medal is the highest award conferred by the society, recognizing the recipient's overall distinction and contributions to the field of optics.

Professor Haus has made enormous contributions to the science of optics and its technological applications, particularly in areas relating to wide-band communications frequently used in Air Force C3I systems. His research has included fundamental contributions to the understanding of noise properties in laser systems and frequency control methods for distributed feedback semiconductor lasers now used routinely in fiber optic communications. With AFOSR support, Haus has made major contributions in the area of stable ultrashort pulse generation from mode-locked lasers which will be used in future wide-band ("information superhighway") networks. His work funded by AFOSR in the understanding and control of instabilities in the transmission of optical solitons (the so-called Haus-Gordon instabilities) will allow very long distance fiber optic transmission at ultra-high data rates. Haus is an institute professor at MIT, the highest faculty rank at the institution. He is the author or co-author of five books and more than 200 publications.

Dr. Howard Schlossberg
Directorate of Physics and Electronics
(202) 767-4906, DSN 297-4906

Rensselaer Polytechnic Institute Researcher Elected to the National Academy of Engineering

Dr. George J. Dvorak, the William Howard Hart Professor of Rationale and Technical Mechanics at Rensselaer Polytechnic Institute, was elected to the National Academy of Engineering in February. The highest honor for a U.S. engineer, the Fellow award recognizes his many significant contributions in the field of solid mechanics. These include his research on metal-matrix composites and the micromechanics of materials. AFOSR has sponsored Dr. Dvorak for nearly 20 years, primarily in the area of inelastic behavior of metal-matrix composites (MMC). He developed the periodic hexagonal-array model, which can model the inelastic behavior of a fiber-reinforced MCC, including plasticity and viscoplasticity. This fundamental micromechanics model has been integrated into methodologies used for life prediction of metal-matrix composites. Dr. Dvorak's research makes it possible to determine the life of metal-matrix composites in advanced gas turbine engines so that higher temperate operation can be realized.

Dr. Dvorak has also worked with the National Aero-Space Plane (NASP) Institute for Composites, jointly managed by the Air Force and NASA. His work in developing transformation field analysis for MMC has been used in modeling the thermomechanical behavior of metal-matrix composites for hypersonic vehicle structures. In addition to these applications, Dr. Dvorak's work is now being used in the MMC Life Prediction Cooperative, managed by the Wright Laboratory. The cooperative includes major gas turbine engine manufacturers such as Pratt & Whitney, General Electric, and Allison. Dr. Dvorak's latest work involves functionally-graded materials, which will give tremendous flexibility to designers of future material systems.

Dr. Walter F. Jones
Directorate of Aerospace and Materials Sciences
(202) 767-0470, DSN 297-0470

AFOSR Principal Investigators Share National Academy of Sciences Award

Dr. Julian Cole, the Margaret Darrin Distinguished Professor of Applied Mathematics at Rennselaer Polytechnic Institute, and Dr. Joseph Keller, the Lewis Terman Professor of Mathematics and Mechanical Engineering at Stanford University, received the National Academy of Sciences triannual award in Applied Mathematics and Numerical Analysis at the National Academy of Sciences annual meeting in April.

Dr. Cole, professionally recognized for his work on transonic aerodynamics, pioneered development of the Transonic Small Disturbance Theory. This theory provided the design basis for Air Force and civilian aircraft, which primarily fly at transonic cruise speeds. These designs promise reduced platform drag and increased engine efficiency. Under AFOSR support, Dr. Cole is investigating the design of shockless airfoils and turbine blades. He is also a member of the National Academy of Sciences and the National Academy of Engineering and served as a member of the Air Force Scientific Advisory Board. AFOSR has supported his work and the development of the Transonic Small Disturbance Theory for more than a decade.
Dr. Keller, noted for his work on wave propagation, is the originator of the Geometrical Theory of Diffraction, which was used to design the F-117 stealth jet. Dr. Keller is presently investigating wave propagation in random media. AFOSR has supported his work for more than a decade.

Dr. Arje Nachman
Directorate of Mathematics and Geosciences
(202) 767-4939, DSN 297-4939

AFOSR Investigator Recognized for Contribution to Scramjet Engines

Professor Frank E. Marble received The Combustion Institute's 1994 Hoyt C. Hottel Award for his work in shock structure and fuel-air combustion research. The Combustion Institute is the premier international, professional organization for combustion research. Professor Marble is the Dorothy M. and Richard L. Hayman Professor of Mechanical Engineering and Professor of Jet Propulsion, Emeritus, at the California Institute of Technology. During his award ceremony lecture he described how AFOSR-sponsored basic research led to the design of a unique fuel injection nozzle for supersonic combustion jet (SCRAMJET) engines for application in hypersonic flight vehicles.

Combustion occurs in SCRAMJETs as the fuel-air mixture flows at supersonic speeds. These high-speed flows reduce the effective time in which combustion can be completed before the propellant mixture is exhausted from the flight vehicle, as well as generating dissipative shock structures within the engine. As a result of these two adverse effects, no successful operational SCRAMJET engine has yet been produced. Professor Marble's research is based on the perception that shocks can also benefit SCRAMJET combustion. His research introduced an approach in which shock structure destabilizes the fuel-air mixture to cause an enhancement of mixing and combustion.

Although Professor Marble's shock structure research did not begin until 1986, it reflects a short transition time from basic research to engine component development and testing. Soon after his research began, the National Aero Space Plane (NASP) Joint Program Office quickly sought its technical exploitation. In 1990, the AFOSR laboratory demonstration of principle was transformed into a fuel injector design that was tested at NASA Langley Research Center under NASP support as a component of its hypermixing program.

Professor Marble has been actively involved in fluid dynamic and combustion research related to propulsion systems for over 50 years at the California Institute of Technology, the National Aeronautics and Space Administration (NASA), the Jet Propulsion Laboratory, Cambridge University, and several other major research and academic institutions. He is a member of the National Academy of Engineering and a Fellow of the American Institute of Aeronautics and Astronautics.

Dr. Julian M. Tishkoff
Directorate of Aerospace and Materials Sciences
(202) 767-0465, DSN 297-0465

RPI Researcher Elected to National Academy of Engineering

Dr. George J. Dvorak, the William Howard Hart Professor of Mechanics at Rensselaer Polytechnic Institute, was recently elected to the National Academy of Engineering. The highest honor for a U.S. engineer, he is being recognized for his many major contributions to the field of solid mechanics, including research on metal-matrix composites and the micromechanics of materials.

AFOSR has sponsored Dr. Dvorak for nearly 20 years, primarily in the area of inelastic behavior of metal-matrix composites (MMC). He developed the periodic hexagonal-array model, which models a fiber-reinforced MMC's inelastic behavior, including plasticity and viscoplasticity. This micromechanics model is integrated into methods used to predict the life of MMC. The model allows a more thorough, comprehensive mechanistic evaluation of internal damage mechanisms versus the more conventional statistical evaluations which require numerous expensive experimental tests.

Dr. Dvorak has worked very closely with the National Aero-Space Plane (NASP) Institute for Composites, jointly managed by the Air Force and NASA. His work developing transformation field analysis has been used to model the thermomechanical behavior of metal-matrix composites for hypersonic vehicle structures. His work is also being used in the MMC Life Prediction Cooperative, managed by Wright Laboratory, which involves major gas turbine engine manufacturers including Pratt & Whitney, General Electric and Allison. The Cooperative seeks to determine the life of metal-matrix composites in advanced gas turbine engines with the goal of achieving the advantages created from higher temperature operations.

Dr. Walter F. Jones
Directorate of Aerospace and Materials Sciences
202-767-0470, DSN 297-0470

AFOSR Principal Investigator Wins Germany's Humboldt Prize

Prof. Parviz Moin, the Franklin P. and Caroline M. Johnson Professor of Mechanical Engineering at Stanford University, recently received the Alexander von Humboldt Foundation's Humboldt Prize. The prize is Germany's highest form of recognition given to a senior U.S. researcher. The award recognizes Prof. Moin's career contributions to research in turbulence, and allows him to spend up to 12 months pursuing research with German colleagues.

The Humboldt award program was founded in 1954 to promote scientific cooperation between Germany and the United States. Nominations for the award must be made by leading German scholars and submitted to the 100-member Central Selection Committee, chaired by the president of the German Research Society.

Prof. Moin is a co-founder and director of the Stanford University/NASA Ames Center for Turbulence Research. He pioneered the development of direct numerical simulations of turbulent flows and instituted a national database of computer-simulated turbulent flows. With AFOSR support he developed the minimal-flow module, explored passive and active control techniques for reducing turbulent drag, and developed and applied Large-Eddy Simulation methods for complex combustor and airfoil flows. AFOSR has funded his research for more than a decade.

Dr. James M. McMichael
Directorate of Aerospace and Materials Sciences
202-767-4936, DSN 297-4936

AFOSR Investigator is Elected to National Academy of Engineers

Prof. Judea Pearl of the UCLA Computer Science department has been elected a member of the National Academy of Engineering (NAE). Pearl, an artificial intelligence expert and an AFOSR grantee for the past seven years, is director of the UCLA Cognitive Systems Laboratory, where researchers study the theoretical foundations of plausible reasoning and heuristics – how machines can use hints and intuition to solve problems. He was one of 77 engineers nationwide to become an NAE member.

Pearl was elected to the NAE for developing the foundations for reasoning under uncertainty. This arises in artificial intelligence when a machine is asked to draw a conclusion about a task based on incomplete information. His effort has been at the center of this research for more than a decade, and he developed many standard notions and techniques. Pearl's early developments included Bayesian belief networks, distributed inferencing, graphoids and qualitative probabilities.

Prof. Pearl's most recent research involves causality: the task of getting a machine to learn cause-effect relationships in an unknown environment, using limited observations and manipulations. The methodology Pearl pioneered for managing uncertainty and understanding causality will have a profound effect on future Air Force diagnostic systems, aids for planning in uncertain environments, integration of sensors, and aids to decision making in mission-critical situations.

Dr. Abraham Waksman
Directorate of Mathematics and Geosciences
(202) 767-7903, DSN 297-7903

AFOSR Investigator Receives Nation's Highest Scientific Honor

In Oct. 18 White House ceremonies, President Clinton presented National Medals of Science to eight people, including Air Force Office of Scientific Research (AFOSR) principal investigator Prof. Hermann Haus of the Massachusetts Institute of Technology.

Prof. Haus was recognized for fundamental and seminal research contributions to quantum electronics, noise and ultrafast optics; and for service to the engineering profession through teaching. AFOSR has funded Dr. Haus's work continuously for 10 years, primarily in mode-locked (especially fiber) lasers, very-wide-band (especially soliton) communications, and generating and applying nonclassical (squeezed) light. His contributions have had a major impact on Air Force technology in lasers and areas related to wideband signal and information processing as applied in command, control, communications and intelligence (C^3I) systems.

The National Medal of Science is the nation's highest scientific honor. The 86th Congress established the Presidential Award in 1959 to recognize outstanding contributions to knowledge in the physical, biological, mathematical and engineering sciences.

Dr. Howard Schlossberg
Directorate of Physics and Electronics
202-767-4906, DSN 297-4906